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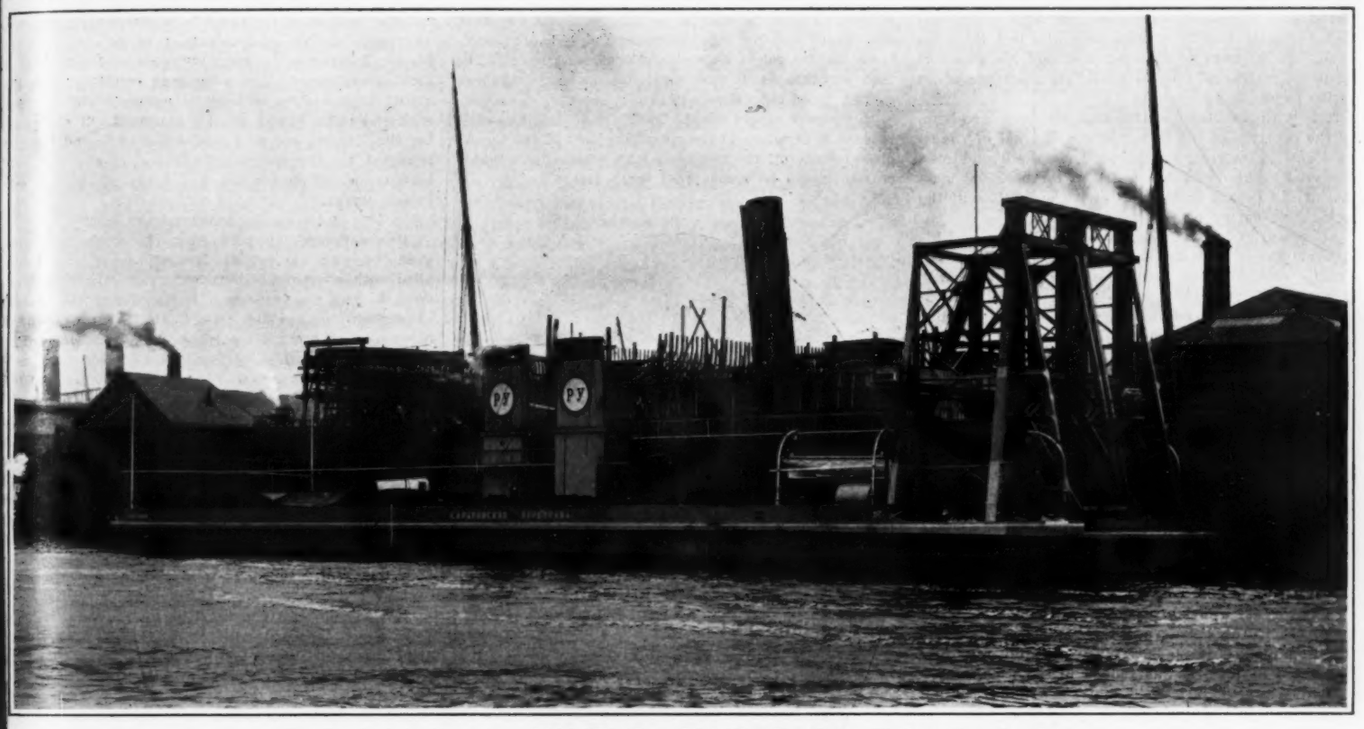
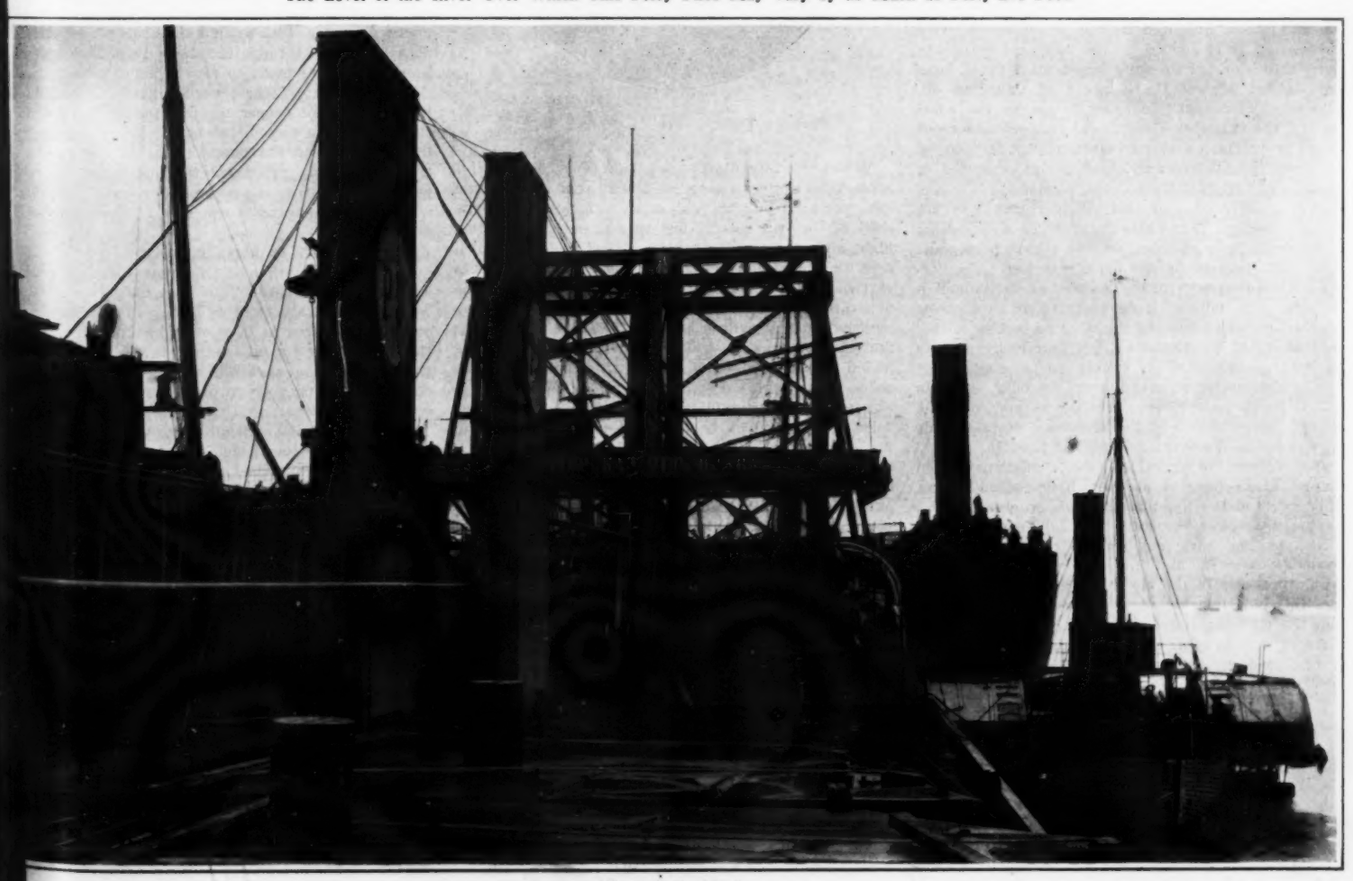


The Level of the River Over Which This Ferry Plies May Vary by as Much as Forty-five Feet.



View of the Deck.

RUSSIAN FERRY STEAMER PLYING ON THE VOLGA.—[See page 152.]

Herman Frasch

Recipient of This Year's Perkin Medal

THERE is, in the bestowal of certain great honors, often a peculiar inversion of the effect primarily intended. When a Clerk-Maxwell appears second on the list Wranglers, or a J. J. Thomson receives the Noble prize, it is not the award that adds a distinction to the man, but the man who gives prestige to the prize.

This year the Perkin medal has been awarded to Dr. Herman Frasch, and one is tempted to say that we have here such a case: in days to come the Perkin medal will be treasured as a distinction bestowed on such a man as Herman Frasch, who not merely added this or that new asset to our wealth of scientific methods in industrial operations, but who revolutionized an entire branch of industry; who had it in his hand, had he been so disposed, and had his generous mind not restrained him, to annihilate the trade of an entire population.

It is with peculiar pleasure that we reproduce here, by the courtesy of the Editor of the *Journal of Industrial and Engineering Chemistry*, Dr. Frasch's address, delivered by him on the occasion of the bestowal upon him of the Perkin medal, and giving an outline of the remarkable career of the great chemist.

After a brief introduction, in which he expressed his appreciation of the medal bestowed upon him, Dr. Frasch went on to an account of his work, especially in connection with the purification of certain mineral oils, and with the mining of the Louisiana sulphur deposits by the method which has made the name of Frasch famous.

OIL.

"Very little is known of the impurities contained in petroleum. They influence the price, however, to a remarkable degree. The best illustration of this is the case of Ohio oil. This contains about 0.75 per cent of sulphur, and before my desulphurizing process was known sold at 14 cents per barrel, while Pennsylvania oil, with a sulphur content of only 0.03 per cent sold at $2.25 at the same time. Sulphur affects the value of petroleum in a greater degree than phosphorus does that of iron ore.

"One of the oils which contains an objectionable amount of sulphur is that found near Pretolia, Ontario. It is the only crude that has been found in the Dominion of Canada. When this oil was first discovered in 1868, it was refined in the usual way—treated with sulphuric acid and soda, and then put on the market. The result was disastrous. The odor emanating from the oil was very offensive and penetrating, so much so that the cargoes of ships carrying flour and bacon, anchored near a vessel loaded with Canadian oil, were spoiled, as the flour and bacon absorbed this odor. Law suits based upon these facts were decided against the shippers of Canadian oil, and all export ceased. In order to protect the home industry, the Canadian Government imposed a duty of 9 cents per gallon on Pennsylvania oil, but in spite of this almost prohibitive duty, half the oil consumed in Canada was imported from Pennsylvania.

"The offensive odor of this oil, moreover, was not its only objection. It had also the property of depositing soot upon the lamp chimney, so that a large percentage of the light emitted by the flame was lost.

"The Canadian Government, as well as the Canadian producers and refiners, made every effort to discover a method by which the objectionable properties of this crude oil could be eliminated, but practically nothing has been accomplished in twenty years, except perhaps in the matter of covering up the odor, when in 1885 I bought a refinery in Canada and made a thorough investigation of the character of this crude and decided to discover a remedy, if possible.

"This dreadful odor, which the Canadians called 'Skunk,' arose from a peculiar hydrocarbon-sulphur compound, and the clouding of the lamp chimney was due to its sulphur content. The sulphur in the oil burned into sulphuric acid, which condensed against the lamp chimney, and any unconsumed carbon of organic particles in the air would adhere thereto and form this objectionable soot. To remove the sulphur from the oil completely meant the elimination of the smoke as well as odor, and when this was effected the oil furnished an illuminant equal in quality to the best Pennsylvania.

"To free petroleum of elementary sulphur or hydrogen sulphide presents comparatively little difficulty, but the sulphur compound which is the cause of this offensive odor is very stable and cannot be broken up into hydrogen sulphide or any other sulphur compound which can be eliminated. It was because of the presence of this peculiar compound that Canadian oil for so many years resisted all the efforts made to refine it.

"This sulphur compound has the peculiarity of dissolving a number of metallic oxides. When the oil is saturated with all the oxide it can carry in solution, the disagreeable odor disappears. It reappears, however, if an attempt is made to free the solution of its metal. I found that this solution of metal in petroleum has an intense affinity for sulphur, and also that when a portion of the surphur has been precipitated with the metal as a sulphide, additional quantities of metal oxide can go into solution. If more oxide than that necessary to precipitate all the sulphur is added to the petroleum while it is being distilled, a complete desulphurization of the petroleum is effected.

"When this petroleum solution is made with water-white petroleum distillate, which has been freed of elementary sulphur and hydrogen sulphide, the solutions assume colors characteristic of each metal. The lead solution is a canary-yellow; mercury, orange; copper, blood-red; silver, brown.

"I selected copper as the metal most suitable—first because it dissolves in the petroleum, and in the second place because of the readiness with which the sulphide of copper can be reconverted into oxide.

Herman Frasch, Perkin Medal, 1912.

"When the laboratory work had been completed, I applied for letters patent and erected a 1,200 barrel still, carrying on the process on a large scale. The shell of the still was 22 feet in diameter and 16 feet high, and was supplied with a stirring device which kept the copper in suspension while distillation was carried on. After 80 per cent of the contents of the apparatus was distilled, the remainder, when cool, was pumped through a filter press. The solid portion was ignited and roasted, while the liquid residuum was mixed with a new charge of revivified oxide of copper to be used for the desulphurizing of a further quantity of sulphur-containing distillate. I used a shelf furnace, operated by hand, to roast the resulting sulphide of copper. In this manner I produced a burning oil containing 0.02 per cent sulphur, which is the percentage contained in Pennsylvania oil of similar specific gravity, while Canadian oil, refined by the ordinary method, has a sulphur content of 0.6 per cent.

"It was about this time that oil almost identical with the Canadian was discovered in Ohio, and while the question of refining Canadian oil was interesting, the problem became intensely important when 30,000 barrels per day were being produced in Ohio. The new field proved to be very extensive, and the Standard Oil Company bought property near Lima, Ohio, upon which they erected a large refinery. They disregarded the enormous difference in the sulphur content of Pennsylvania and Ohio oils, decided to refine the latter in the usual way and put it on the market. When the refined product had been distributed among their customers, it all came back as unfit for use. Every effort was made to solve the difficult problem, but in 1887, after two years of experimentation and with all the skill which the Standard Oil Company could call to their assistance, it was decided that no illuminating oil could be made from Ohio crude and that it was fit only for fuel. A pipe line for this purpose was built to Chicago, and long-term contracts made at 14 cents per barrel.

"My patents had now been granted and I was selling refined Canadian oil with a guarantee that it would burn equal to the best Pennsylvania. After an investigation which convinced them that I had solved this problem, the Standard Oil Company bought my patents and my refinery, and as soon as possible Lima, Cleveland, Whiting, Philadelphia and Bayonne were refining oil by the new method.

"The Ohio field was found to extend into Indiana and the production increased to 90,000 barrels per day. The price of this crude went up to nearly $1.00 per barrel, fluctuating between 60 cents and $1.00 for a great many years. The advantage resulting from the ability to use these oils for illuminants did not stop with the large profits of the Standard Oil Company, but the farmers and oil producers of Ohio and Indiana benefited by the enormous advance in the value of Ohio crude, which amounted to many millions of dollars per year.

METHODS OF DESULPHURIZATION.

"In desulphurizing petroleum, the oxide of copper is mixed with the petroleum distillate in a still supplied with an upright shaft and arms radiating therefrom, to keep the oxide in agitation during the process of distillation, flexible chains attached to the arms being used to prevent the copper from adhering to the bottom of the still. One hundred thousand pounds of oxide of copper are used for the first charge of 2,000 barrels of distillate. After 80 per cent has been distilled off, a new charge of distillate is added with an additional charge of 30,000 pounds of copper which is followed by two further runs, so that about 200,000 pounds of copper material are in the still when the fourth run is made. The residuum is pumped through a filter press, and the solid product of the filter press has the oil adhering thereto burned off. The dry mixture of oxide and sulphide of copper is then put into a roasting furnace, where it is desulphurized to 1 per cent or less.

"A variation of my method treats the vapor coming from a still charged with crude petroleum, and consists in passing the vapor through two brushes made of No. 10 steel wire, the brushes 5½ feet in diameter and 16 feet long. They are inserted into a shell which is almost the same diameter as the brush, and the requisite amounts of copper and heavy oil are pumped into two shells, each containing one brush. The vapor passes in series, first around the shell to prevent condensation; then through the shells on to the condenser. The brushes are made to revolve at about six revolutions per minute. These wires immersing continually in this oxide of copper magma, the shells containing the brushes are surrounded by the vapor coming from the still, and as the temperatures of the vapors increase, anything condensed thereon during the prior period is re-evaporated by the hotter vapor following.

"Both these processes are now in operation at different works.

ROASTING FURNACE.

"When the question of supplying the copper necessary for the works at Lima was under discussion, it was found that 160 furnaces, such as I used in Canada, would be required to do the work. In order to avoid the handling and transportation involved in such a gigantic furnace plant, I was obliged to construct a mechanical roasting furnace of a capacity in conformity with the magnitude of the business.

To eliminate the difficulties of the warping of the shaft and the arms which had caused the failure of the McDougal furnace, I constructed a stirring device the shaft and arms of which were cooled artificially to withstand the high temperature of the roasting furnace. I first forced air as a cooling medium through the stirring device, but found that the oxidation of the sulphide of copper and the carbon from the residuum of the petroleum produced a temperature even higher than that of the ordinary pyrites furnace. It therefore became necessary to substitute hot water for air as a cooling medium, which proved very satisfactory. This made possible an increase in the size of the furnace to 16 feet inside diameter, and to-day these shafts and arms are connected with steam drums and are used like a water tube boiler, so that the surplus heat extracted from the stirring device of the roasting furnace is converted into steam and utilized in the plant. The capacity of a furnace is fifty tons per day, and four to six are used in one refinery. After the copper has been revivified, it is ground and mixed with residual oil from the filter press. In this manner the copper charge is pumped into the still which may be half a mile away. During the twenty years that this process

has been in operation many millions of barrels of oil have been desulphurized.

CALIFORNIA OIL.

"In 1902 the California field became important, and it was discovered that another oil which smoked chimneys had to be refined. This oil, however, was practically free from sulphur, the smoke being due to a large percentage of the aromatic series of hydro-carbons and to the fact that the percentage of hydrogen to carbon was too small to maintain the flame temperature necessary to consume all the carbon. I ascertained further that sulphuric anhydride converts the aromatic series into sulpho products, insoluble in petroleum, and that by treating the distillates from the crude oil with sulphuric anhydride, the members of the aromatic series in the petroleum can readily be extracted.

"The existence of a petroleum containing nearly 50 per cent of the coal tar products is intensely interesting, especially in view of the theories advanced upon the origin of petroleum. The percentage of these hydrocarbons in the crude varies from the percentage contained in coal tar, benzol existing in a smaller proportion than toluol, while xylol represents 7 per cent of the volume of the crude. Naphthalene, entirely free from all traces of carbolic odor, is quite prominent, while anthracene and carbolic acid (phenol) are entirely absent.

"I employed numerous methods for separating the products of California crude by physical means. Distillation, with large back-flow condensers attached, showed very encouraging results, as did also the method of washing the distillates with alcohol, carried on in series, the aromatic series being more soluble in alcohol than the paraffine series. However, the sulphuric anhydride treatment, which I first used in determining the amount of the two series contained in the petroleum, has proved to be very simple and effective on a large scale, and is now used by the Standard Oil Company at their plant in Port Richmond, California. The process of making the sulphuric anhydride employed there is the one purchased from the Verein Chemischer Fabriken of Mannheim. The capacity of the plant has been increased a number of times, until to-day it is by far the largest in the United States, if not in the world.

SULPHUR.

"In 1865, while boring for petroleum in Louisiana, a sulphur deposit was discovered beneath a layer of quicksand about 500 feet thick. As a result of this discovery, quarrels and controversies arose as to whether the lease covering the petroleum rights also included the sulphur. It was some time before the matter was decided, and by the time a decision had been reached, both parties had lost a great deal of money, and those who got the sulphur deposit lost still more in trying to exploit it. The deposit seemed to bring misfortune to every one connected with it, and I have heard many stories and met many people who told me of having lost money in the various schemes that marked the progress of the sulphur mine. Progress there seemed to mean failure. An Austrian company, a French company, and numerous American companies —everybody failed and not a ton of sulphur was produced.

"When I heard of this extraordinary situation, in 1891, I obtained a core from the sulphur deposit and many pamphlets from the various companies who had tried to operate it, each one telling the prospective purchaser that his fortune was made if he but owned a few shares of the stock of that particular company. I became interested, and having had a great deal of experience in drilling and mining petroleum and salt, I thought the problem might be solved if all the facts concerning the deposit were known. Unfortunately, all the drilling records had been colored by the people who expected to float companies—everything unfavorable was concealed, and only that given which would be likely to induce investment, so that what I had considered a correct report proved later to be entirely wrong.

"Being misinformed as to the character of the deposit, I reached the conclusion that the sulphur was distributed in the rock as in Sicily, and when I heard of the limestone roof covering the deposit, I felt that sulphur could be found anywhere within reasonable proximity to the sulphur mine.

"To meet the extraordinary conditions existing in this deposit, I decided that the only way to mine this sulphur was to melt it in the ground and pump it to the surface in the form of a liquid. After careful study and consideration, I became convinced that this could be done. In view of the information obtained from the various companies, I believed that there was sulphur over miles of territory, and started to drill on land I had purchased within a mile and a half of Sulphur Mine. I went down over 2,000 feet without finding anything, then I locat[illegible] second, a third, and a fourth well, but found no s[illegible]hur in any instance. This took much time and money, and I finally reached the conclusion that all the sulphur was located on the land owned by the New York company operating it at the time. They had a very ingenious scheme for sinking a shaft with a shield, but after the expenditure of a great deal of money, the shield was lost, and the danger due to the presence of water containing hydrogen sulphide was demonstrated by the death of a number of men. It was decided to abandon this method, especially after a drilling record had been made by a drilling company who reported direct to the owners, when it was discovered that there was no roof over the sulphur, and that sulphur water was permeating the deposit in inexhaustible quantities.

"I realized at the outset that a method entirely different from that employed in the mines of Sicily was necessary for success here, as the class of labor required to operate this mine would demand at least $5.00 per day, while the Sicilian miners were being paid 60 cents.

"I succeeded in getting possession of the property and at once set to work to drill a well of sufficient diameter to determine finally the character of the existing material. When this had been done, I was obliged to modify completely the process and apparatus I had expected to employ.

"At that time the drilling of a well in an alluvial deposit containing quicksand, etc., was a very tedious task, and it took from six to nine months to get through the alluvial material to the rock—work which we do now in three days.

"I drilled a well through the alluvial deposit to the rock with a 10-inch pipe, then continued through the sulphur deposit, which was about 200 feet thick, with a 9-inch drill, and immersed a 6-inch pipe from the surface to the bottom in this well. The 6-inch pipe had a strainer only 6 inches long, at the very bottom, and a seat to receive the 3-inch pipe through which we expected to lift the sulphur to the surface. The 6-inch pipe, directly above the seat for the 3-inch pipe, was also perforated for a distance of three feet.

"After the well had been drilled and before the pipes were inserted, it was filled up with sand in order to insure a tight receptacle at the bottom for the liquid sulphur. After the sand had been washed out, the pipes were inserted and equipped, and the well was ready for the melting fluid.

"This melting fluid consisted of water superheated to 335 deg. Fahr. The porosity of the rock in which the melting had to be done seemed to furnish an almost insurmountable obstacle to success, as I feared that the wild waters in the rock would break into the melting zone I expected to create and reduce the temperature of the fluid with which I expected to melt below the temperature necessary to fuse the sulphur. I had supplied a large number of boilers to furnish the heat necessary to maintain in the well a temperature higher than that required for the fusion of the sulphur.

"The water was superheated in columns in which 100 pounds per square inch pressure was maintained, and the apparatus which I had constructed to accomplish this proved very efficient. We used twenty 150 horsepower boilers for a well, which represents experimentation on a ponderous scale.

"When everything was ready to make the first trial, which would demonstrate either success or failure, we raised steam in the boilers, and sent the superheated water into the ground without a hitch. If for one instant the high temperature required should drop below the melting point of sulphur, it would mean failure, consequently intense interest centered in this first attempt.

"After permitting the melting fluid to go into the ground for twenty-four hours, I decided that sufficient material must have been melted to produce some sulphur. The pumping engine was started on the sulphur line, and the increasing strain against the engine showed that work was being done. More and more slowly went the engine, more steam was supplied, until the man at the throttle sang out at the top of his voice, 'She's pumping.' A liquid appeared on the polished rod, and when I wiped it off I found my finger covered with sulphur. Within five minutes the receptacles under pressure were opened, and a beautiful stream of golden fluid shot into the barrels we had ready to receive the product. After pumping for about fifteen minutes, the forty barrels we had supplied were seen to be inadequate. Quickly we threw up embankments and lined them with boards to receive the sulphur that was gushing forth; and since that day no further attempt has been made to provide a vessel or a mold into which to put the sulphur.

"When the sun went down we stopped the pump to hold the liquid sulphur below until we could prepare to receive more in the morning. The material on the ground had to be removed, and willing hands helped to make a clean slate for the next day. When everything had been finished, the sulphur all piled up in one heap, and the men had departed, I enjoyed all by myself this demonstration of success. I mounted the sulphur pile and seated myself on the very top. It pleased me to hear the slight noise caused by the contraction of the warm sulphur, which was like a greeting from below—proof that my object had been accomplished. Many days and many years intervened before financial success was assured, but the first step towards the ultimate goal had been achieved. We had melted the mineral in the ground and brought it to the surface as a liquid. We had demonstrated that it could be done.

"This was especially gratifying as the criticisms I had received from technical papers and people who had heard of what I was attempting to do had been very adverse. Every one who expressed an opinion seemed to be convinced that this thing could not be done, one prominent man offering to eat every ounce of sulphur I ever pumped. A fair illustration of public opinion is the remark of the mail boy who drove me to the railroad the morning after our first pumping. He said: 'Well, you pumped sulphur sure, but nobody believed it but the old carpenter, and they say he's half crazy.'

"This severe criticism, while not agreeable, did not carry very much weight with me. I felt that I had given the subject more thought than my critics, and I went about my work as best I could, thoroughly convinced that he who laughs last, laughs best.

"At first we pumped with an ordinary deep-well oil pump, changed to meet the corrosive action of the sulphur. We experienced great difficulty with the valves in the pump, the high specific gravity of the sulphur, the great depth from which it had to be raised, and the corrosive action of the mineral itself making the maintenance of valves very difficult. Zinc and aluminium are practically the only two metals unaffected by liquid sulphur, but both these, being soft and easily disintegrated, would not withstand the shock at the change of stroke of the pump. I decided that if the specific gravity of the sulphur could be lowered by the admixture of some other body much lighter, a point might be reached where the hydrostatic pressure of the water in the ground would raise the sulphur. Air seemed the most suitable, and we introduced compressed air into the column of liquid sulphur standing in the well, using a volume of two parts of air and one of sulphur. We have raised our sulphur discharge lines 70 feet above the ground, so that we can fill bins to a height of 65 feet without machinery or pump of any kind in the sulphur proper.

"The first well lasted long enough to demonstrate the possibility of success, and to indicate in what directions improvements must be made. At that time, my sulphur enterprise was merely a hobby, the bulk of my time devoted to my Standard Oil work.

"Many difficulties arose which we had not foreseen. We lost some wells because of the parting of the pipes. As the mineral was melted from the bottom, the earth above would follow as the sulphur rock settled. The grip of the sand and earth against the pipe was so great that instead of sliding, it would pull the pipe in two and the well would be lost. A 12-inch pipe outside of the 10-inch, with stuffing box and telescope joints, obviated this difficulty. All wells, however, are eventually broken and crushed, when the abstraction of sulphur becomes so great that the cavity made cannot withstand the weight of the ground above it.

"We succeeded in increasing the life of a well greatly by lining the hole drilled through the rock with a 9-inch perforated pipe.

"About that time we found that some wells gave out and ceased to pump when there had been no breaking of the pipes. I reached the conclusion that the cold sulphur water permeating the rock had broken into the melting zone, and brought the temperature of the melting water below the melting point of sulphur. I thought this might be remedied by pumping large amounts of a material like sawdust into the mine with the melting fluid, and that if the quantities of sawdust were large enough, the channels through which the wild waters in the rock entered the melting zone could be sealed.

"One well, after pumping about 7,000 tons, at the rate of approximately 350 tons per day, ceased to produce. The pipes were all in good order, and we started to pump sawdust into the ground with the melting water. After pumping in about six carloads per day for five days, the well 'sealed' with sawdust and promptly produced 39,000 tons more before the caving of the rock broke the pipes.

"We perfected this method of artificially 'sealing' the rock surrounding a melting zone, so that the amount now obtained from a well has been greatly increased. Whenever a well breaks, we shoot off with dynamite the 10-inch pipe in the quicksand above the rock, and permit the sand to follow into the cavity from which the sulphur has been abstracted, filling up the space of the extracted sulphur rock with sand. The surface, consisting of about 200 feet of clay, follows the quicksand, gently but surely, and in order to maintain the pressure which is necessary to prevent the melting water from breaking into steam, the volume of the sulphur abstracted from below must be replaced by earth from above. To do this a dredge with a capacity of 4,000 cubic yards per day became necessary. Numerous reservoirs have been dug on the outskirts of the

mine to supply the material required to do this. This filling has been going on constantly, and the ground has sunk to such an extent that where our house once stood is now 80 feet below the original surface.

"These improvements were made slowly, as all experiments had to be made on a ponderous scale and the smallest change required a great deal of time. During the long intervals which necessarily elapsed between my visits to the mine, I could give this new enterprise no attention. It took months to drill a new well when an old one was lost. At one time the work lay idle for a whole year before I could take it up again, and it was not until 1903 that we could see financial success ahead. In that year we produced 35,000 tons, and in 1904 enough to supply the entire consumption of the United States. It was in that year that we sent the first cargo of American sulphur to France.

"In order to demonstrate what the mine could do with six wells, we pumped that number simultaneously for two months, producing 122,000 tons of sulphur, which is more than the consumption of the whole world for that period of time.

"Prior to the development of the Louisiana sulphur mine, the sulphur production of the United States was less than one-half of one per cent of its consumption, practically the entire amount required being supplied by Sicily and Japan. The former really had a monopoly of the sulphur business for a great many years. The Sicilian sulphur industry was closely interwoven with the politics of the islands, both internal and external. It was in 1833 that an English fleet appeared in the Bay of Naples to compel the Italians to rescind the sulphur monopoly that had been granted to France.

"The ups and downs of the Sicilian sulphur business are extraordinary. The people, a large percentage of whom are employed in the mines, are very poor and used to be in the hands of dealers and usurers, who manipulated the sulphur market to suit themselves, and extremely high prices and extremely low prices followed each other as suited their convenience.

"In England a process had been discovered for the recovery of sulphur from the waste products of the Leblanc soda process, quite a large amount of money being invested in the necessary machinery. When another sulphur crisis occurred in Sicily in 1894-5, and sulphur sold below the cost of production of English recovered sulphur, a number of English capitalists decided to finance and market the Sicilian output. They incorporated as 'The Anglo-Sicilian Sulphur Company,' and succeeded in getting between 75 and 85 per cent of the Sicilian mine owners under contract for the entire output of their mines, whatever that might be, at a fixed price. This arrangement was made with the consent of the Italian government for a term of five years, with the privilege of renewal for five years more. The scheme proved an excellent one, both for the Anglo-Sicilian Company and for the Sicilians. The former made a great deal of money, paying about 50 per cent per annum on their common stock, and reserved large sums for contingencies. The contingencies arose in the form of the Louisiana sulphur production which came like a bolt out of a clear sky. They had received complaints from their agents here that the business in the west had diminished on account of sulphur furnished from a mine that was no mine at all, but where the sulphur came out of the ground ready to ship. The Anglo company, as well as the Sicilians, declared that this was impossible, and that the whole thing was an 'American swindle.'

"I was very anxious to get all the business possible, as our stock pile was much larger than our bank account, and I was surprised to hear that the Anglo-Sicilian Company had accepted a contract for 20,000 tons to be delivered in America, very much below the price they generally quoted, and not far above their cost. I decided to go to London and have a talk with them in order to find out if it would be necessary for us to put the price below their cost in order to maintain the American business which we needed very badly. I was perfectly frank and explained our position fully. I met with a great lack of enthusiasm for this 'American humbug,' and was told that they would go their own way, and I could go mine. I did. I had arranged for the sale of our sulphur in the various European countries, and knowing the production cost to my competitors, I succeeded very shortly in demonstrating that Louisiana sulphur was not a swindle. I found out afterward that the lesson had cost the Anglo-Sicilian Company 285,000 pounds sterling—but then we were friends. Their attitude changed greatly, and they decided to go out of business and let the Sicilians and Americans take care of themselves.

"The Anglo-Sicilian Company, especially during the last years of its life, had found it necessary to store a great deal of the sulphur tendered to them on their contracts, as they had lost the American market, which was their best customer, and it looked very much as though this enormous accumulation, approximating 500,000 tons, would have to be thrown on the market to be sold for whatever it would bring. To the poor Sicilian miner, whose lot under the most favorable circumstances is not an enviable one, this would have meant sulphur below cost, with the eventual closing of the Sicilian mines and misery and starvation to a large population.

"The men well acquainted with the situation felt, as I did also, that this would result in revolution and bloodshed for Sicily. The laborers could not live on a wage lower than that which they already received. Frequent strikes and disturbances occurred when the misery of the working people was greater than usual.

"Understanding the peculiar character of the Sicilians, the government, when the matter was brought to their attention, decided to form an obligatory trust, so that no sulphur would be sold below cost, and the government was to finance the large stock on hand by issuing bonds and guaranteeing the interest. All the Sicilian sulphur mines were to be included in this obligatory trust, and the government agreed to advance, in cash, four-fifths of the value of the sulphur when it was received from the mine owners, the remainder to be paid to them after payment for the sulphur sold had been received and the expenses of conducting the business deducted.

"A law creating this obligatory trust, which is known as the '*Consorzio Obbligatorio per l'Industrie Solfifera Siciliana*,' was passed, and it has now been in operation since August 1st, 1906. It has gone through the vicissitudes and occupies a unique position among the various trusts, which is of special interest to the United States. Here we have in successful operation a trust created by force, which all those engaged in that particular business are obliged to join. It has a board of thirty directors, an executive committee of ten, four of whom are members of the government, and a royal commissioner, also appointed by the government, who is practically its president. Prices are fixed and maintained, and sulphur is sold to all comers at the same figure.

"This obligatory trust has been a godsend to the people, and so well are the Sicilians satisfied with its operation that they have already petitioned the government to extend the period of its life beyond that originally decided upon. Moreover, the present commissioner's able and wise administration has been so successful that the Sicilian stock of sulphur on hand and the obligation of the Consorzio toward the government and the Bank of Sicily have been diminished to such an extent that the stock will be reduced to normal within two years and the Consorzio will be entirely out of debt. It is a striking illustration of the fact that a trust may be beneficial to all concerned. Great credit is due to the Italian government for averting the misery which would inevitably have followed another sulphur crisis."

The Purity of Natural Waters—II.*

The Influence of Aquatic Organisms, of Domestic Sewage, and Industrial Waste

By Maximilian Marsson

(Continued from Supplement No. 1887, page 131)

Summer and Winter Effects.—Another significant factor must also be mentioned. In the examination of the plankton of small bodies of water, it was noticed that as many organisms of different kinds were found in winter as in summer. The algæ that were held in suspension in the water and constituted the phyto-plankton, seemed to thrive as well during the short daylight of the winter as in summer, and thus maintained a similar constancy of the zoo-plankton. The variation of the temperature, therefore, had no effect, and the only other difference was in the mode of nutrition. It had previously been found that in addition to the matter obtained by assimilation, diatoms could absorb albuminous or similar nitrogenous compounds from the medium surrounding them, and hence that they derive their food from two distinct sources. Subsequent physiological experiments showed that diatoms as well as green algæ can not only absorb carbon compounds from dissolved organic matter, but also organic nitrogen; and that when carbonic acid is rigidly excluded from the water they can digest diluted volatile fatty acids, amido-acids, skatol, urea, peptone, and other substances. Quite recently it was proved that certain diatoms, especially some of the marine varieties, were entirely devoid of chromophyll, or the coloring matter required for assimilation; that they subsisted exclusively on the products of decomposition derived from their surroundings, without recourse to assimilation; and hence that they needed only a medium containing a sufficient supply of food of various kinds. Such algæ have accordingly become true saprophytes, or residents of putrefying matter, and by giving up their chromophyll they have taken the last step from a mixotropic to a heterotropic nourishment.

This direct absorption of dissolved organic matter by algæ is of the utmost importance for the purification of streams by eliminating therefrom the soluble products of putrefaction. As all the algæ that are held in suspension in the water of a river, as well as those that are lodged on the bed and shores, are busily engaged day and night in the work of producing fresh albumen, starch, and indirectly fats, from animal and vegetable refuse matter, it follows naturally that numerous animal organisms will develop in the water to make use of these products and convert them into living flesh.

Through these various investigations and the cyclical transformation of matter, it has become possible to understand how a constant biological self-purification takes place in our streams and lakes, even during the winter and under the ice, and that the maintenance of the plant life insures the continuation of the animal life in the water.

Molds or Fungi.—A similar mode of nourishment is exhibited by the Molds or Fungi. These plants cannot assimilate inorganic matter, like those having chlorophyll, but must rely for their food on the presence of other organisms or of suitably prepared organic matter. They represent the realm of darkness and received the penalty which Nature has placed on the giving up of independent nutrition; they are either parasites or saprophytes, that is to say, they subsist on the products of the decomposition of dead organisms and vegetable and animal refuse matter, such as is contained in the sewage of cities and the wastes of factories.

Bacteria.—The first of these organisms to appear in the water after the entrance of putrefying matter into a stream, are the Bacteria (Schizomycetes). They multiply most rapidly where they find the most food, but they also consume oxygen. The more extensive the bacterial processes, the greater will be the consumption of oxygen, and the more favorable will become the conditions for the existence of animal life which is dependent on the presence of oxygen in the water. By the removal of the oxygen the respiration of most living organisms is stopped, and they are thus deprived of that source of energy which is essential to the performance of their functions. If the green algæ did not counteract the bacterial consumption of oxygen by constantly producing a new supply of this gas, our rivers would soon become completely poisoned and fouled by the continuous discharge of putrescible matter into them, as is now done by our large communities. The fact is, however, that a large proportion of the microbes in the sewage of our cities dies naturally soon after reaching the rivers.

The bacteria must not be regarded as enemies exclusively, as they are a necessary factor in all processes of decomposition that take place not only in water, but also in the whole economy of Nature. Their most important function is to liquefy the organic components of dead vegetable and animal matter, and render them capable of being absorbed by living plants. They decompose proteids, or albuminous substances, by abstracting therefrom ammonia, which is then oxidized to nitrous and nitric acid by certain nitrifying organisms. In this manner the decomposed organic raw material begins anew its course in the circulation of matter. For the formation of new food and soluble compounds of nitrogen, such as salts of ammonia, nitrites and nitrates, are of primary importance, and next comes phosphates, silicates and other salts.

The magnitude, and eventually the cessation, of this new production of food is governed by Liebig's law of the minimum, according to which the energy of vegetation is limited by the energy of the least quantity

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of indispensable food material that is present. As soon as this is used up, further life comes to a standstill.

In the action of bacteria upon the dissolved nitrogenous matter that reaches the streams, a difference occurs in different seasons. The decomposition of putrescible material proceeds much more actively and quickly in the warm season, while in winter the phyto-plankton and the filamentous fungi of the water consume a large proportion of this material by their peculiar mode of nutrition; but at higher temperatures the nitrites and nitrates resulting from the mineralizing processes that take place in the water are decomposed by the separation of free nitrogen therefrom. This decomposition is effected by Denitrifying Bacteria, which often require a relatively high maximum of temperature. By their activity in the warm season, when the processes of decomposition are most energetic, the poisoning of the water by inorganic compounds of nitrogen is prevented. The free nitrogen, however, cannot be utilized in appreciable degree for the structure of aquatic plants, and it is accordingly lost in the circulation of matter in water.

The orderly relations between the conditions of production and the actual production are determined to a large extent by the despised bacteria. Brandt has formulated some important considerations in this direction in his study of the circulation of matter in the sea; and it appears therefrom that the disturbing activity of the denitrifying bacteria is associated with the remarkable fact that the magnitude of production in the oceans of the arctic and temperate zones is not inferior to that of the tropical seas. This is directly contrary to the activity of land organisms, which exhibits a large decrease in production in proceeding from the tropics toward the poles. In the warm seas a relatively smaller production can take place, in spite of much more favorable conditions, in consequence of the greater decomposition of an indispensable substance of plant food, corresponding to the law of the minimum, while in the cold water a greater quantity of nitrogenous compounds is available to the marine producers, owing to the retardation or suppression of this decomposition.

It is not our purpose to consider here various other bacteriological details, such as the vitality of pathogenic germs in river waters.

A series of other fungi adapted to aquatic life also play an important part in the purification of streams. Foremost among these may be mentioned the filamentary bacteria, of which Sphærotilus Natans is the most widely distributed species. This fungus is found in all places where extensive processes of putrefaction take place in water, and especially at the points where liquid wastes containing much nitrogenous organic matter are discharged. Such liquids are chiefly the sewage of cities and the wastes from sugar, starch, glue and cellulose factories, breweries, distilleries, etc. The stronger the pollution, the greater will be the development of sphærotilus, which will be rendered visible by thick whitish flocculent growths on submerged leaves. Under certain conditions Leptomitus Lacteus will also appear, although this aquatic fungus is much more highly organized. Under different conditions other varieties will develop, but none of these deserve as much consideration as the Sulphur Fungi, which constitute another large group.

Beggiatoa.—Among these the Beggiatoa are of most significance for a river, as my observations have shown that the other sulphur bacteria, and especially the red ones, are found more generally in stagnant water. The beggiatoa, of which a number of species are known in southern waters, can exist only in flowing water; that is to say where a supply of oxygen is available. Individual filaments of this fungus can always be found in examining microscopically samples of any river mud of sludge, but its rapid growth takes place only when sulphuretted hydrogen is presented as a product of the putrefaction of albuminous substances derived from either vegetable or animal matter. The beggiatoa separate the sulphur from the sulphuretted hydrogen and store it in their cells. Sulphur is an important source of energy for these plants, and serves the same purpose as carbon for the other organisms in the process of breathing or transpiration. It is, however, not assimilated, but becomes oxidized into sulphuric acid by the oxygen present in the water, and this acid then combines with the lime that is in solution in the water to form gypsum. These sulphur fungi thus have the highly important function of removing from the water the sulphuretted hydrogen that is so dangerous to animal life, and is so offensive æsthetically.

Pollution Indexes.—When found in large quantity in a stream, the various fungi mentioned above afford reliable evidence that the water has been polluted in higher degree than is usual under natural conditions, and they accordingly serve as guides to the source of the contamination. All of them have a great purifying power, but where large quantities of marsh gases rise from putrefying mud, they become entirely powerless, as the bacteria of putrefaction are then exclusively at work. The discovery of guiding forms of fungi has become of great importance in arriving at a correct judgment of the quality of a water, as they furnish us with much more characteristic and quicker results than the chemical analysis of samples of water taken arbitrarily.

We must also bear in mind another physiological process by which plants manifest further similarities in metabolism or change of matter to that of animals. A plant builds up its substance in the same manner as an animal, by forming directly usable food material, especially albumen, from the carbohydrates (sugar and starch) acquired as previously described and from nitrogeneous compounds, for the maintenance of the molecules of living protoplasm; and it is also capable of respiring or breathing like an animal, in the daytime as well as at night, when the activity of assimilation has declined. In this process of breathing or transpiration, which is, however, not localized as in many animals, a plant also gives off carbonic acid and absorbs oxygen, like an animal. The same is likewise true of the bacteria in addition to their fermentative activity.

If the materials which are produced in the green cells of a plant from inorganic food remained therein unaltered, they would represent an accumulated dead capital. By the breathing process, however, the heat which is made latent in assimilation becomes liberated by the decomposition of a portion of the carbohydrates. When there is a deficiency of oxygen in the water, as happens from the discharge therein of putrescent liquid wastes, the aquatic plants are deprived of the possibility of breathing and must perish; this fate befalls the higher classes of aquatic vegetation as well as the lower ones, like the algæ and especially the phyto-plankton.

The breathing or transpiration of plants is also accompanied by certain disadvantages in the case of stagnant bodies of water, in which the oxygen consumed by the animal life is not restored during the night. Thus it was observed that in trout ponds which contained an excess of filamentous green algæ numerous fish died about daybreak, having been suffocated from lack of oxygen. The more intense the growth of such aquatic plants during the day time, the more energetically will their breathing process proceed; and this may readily exhaust during the night the greater part of the oxygen contained in a confined body of water, especially in the warm season. This breathing is really a combustion of carbon compounds; and as such combustion is facilitated by an increase of temperature, it follows that up to a certain limit the transpiration of the algæ will be the more copious in proportion as the temperature of the materials and their surroundings increases. A reasonable explanation is thus at hand for so unusual a phenomenon as the death of a healthy fish in pure water.

The Boundary Line Between Plants and Animals.—In the foregoing much consideration has been given to the aquatic food producers, whose significance in maintaining the purity of our streams has not been recognized sufficiently up to the present time; and we have also become convinced that the animal world with its innumerable species is dependent on the synthetic work performed by plants. No animal is capable of making, like the plant, the food required for its maintenance out of inorganic matter; and this fact affords a marked distinction between plants and animals, or between food producers and food consumers. The boundary lines that were formerly drawn between the animal and vegetable kingdoms have been obliterated by recent investigations. There are, however, many organisms of doubtful character, in which the peculiarities of both kingdŏms are more or less mixed and blended, and which are therefore claimed by both botanists and zoologists. Such organisms possess the fundamental properties of living protoplasm, namely, sensation and motion, which are fully developed in the higher stages of animal life, while in plants they are manifested only in exceptional cases.

The Green Flagellates, which move by means of their flagellæ, must be regarded as plants, as they excrete oxygen by means of their chloroplasts. This peculiarity does not belong to any animal.

Among these flagellates the Euglenas are of great importance in the transformation of putrescent matter. They not only absorb such matter directly, but they also produce oxygen while in the sunlight, and thus oxidize compounds that have been reduced by putrefactive fermentation, as well as offensive gases. The Euglenas and their relatives are therefore found mainly in nauseous pools, whose surface they cover with a green scum. They appear on every sewage farm, and especially on the surface of sewage held in tanks. They also develop in great numbers in sluggish indentations of the banks of polluted streams, from which they are carried along by the current, When found plentifully in the plankton, they afford proof that the water has been contaminated.

Modes of Suspension.—It is evident that the microfauna which are provided with well-organized means of motion can remain suspended in the water more easily than the micro-flora. If the term "plankton" is understood to embrace all living organisms that float or move involuntarily in a body of water, it becomes necessary to determine by microscopical examination how the ability of the organisms to remain in suspension is attained. Primarily, this will be increased by a considerable enlargement of the surface of the cells in proportion to the volume. In the case of the algæ, and especially the silicious algæ, the individual cells are provided with hairs or spicules which are sometimes arranged so as to act like a parachute; in other species the cells form colonies shaped like a ribbon, a chain, a star, etc., whence they are designated as belonging to the ribbon, chain, or star type, while others are spindle or drum-shaped. Such extensions of body are also very common in animals, especially in certain crustaceans. Lastly, but not in least degree, the products of assimilation are of importance in regard to suspension, such as the formation of fat in diatoms and the excreted gases in colonies of algæ. By these various structural and functional means for remaining in suspension, a nearly uniform distribution of the constituents of the plankton is accomplished. This varies with the time of day in the different strata of the water, and thus insures a thorough utilization of the organic matter by the plants. In water strongly contaminated by dissolved organic matter, it is difficult to find a single drop that does not contain some living organisms which are constantly engaged in the work of purification.

Plankton-Producing Capacity of Waters.—The capacity of our waters to produce plankton may be indicated by a single example. During the months of February, March, and April, a species of diatom called Melosira Lævissima constituted the main portion of the plankton in Great Plöner Lake; and it was estimated by Zacharias that in the middle of March the aggregate weight of these minute plants, reckoned as fresh substance, was 31,000 cwt., as a single draft of the plankton net at a depth of only 8 feet, (2.5 meters) yielded about 16,000,000 Melosira cells. Such organsims vary in kind with the conditions for nutrition and propagation, and these in turn depend on thermal influences. The annual periodicity or seasonal distribution of the plankton is therefore variable. The maximum is reached under the favorable conditions of light and heat in summer, when the plankton has to perform its hardest work and is required to remove matter which putrefies more rapidly at a high temperature.

Under relatively unfavorable conditions of the flowing water of the river Elbe, near Hamburg, R. Volk found 33,650 algæ per cubic centimeter, counting the colonies and cenobes onlyas units. Still greater is the number of algæ in water of a greenish color, like that of Lietzen Lake, in which R. Kolkwitz counted about 400,000 algæ cells per cubic centimeter. It is thus seen that Nature always acts in a helpful manner; but her powers in the purification of water have not yet been sufficiently appreciated, and often her help is not only rejected, but is also directly nullified by the addition of too large a quantity of chemicals to the contaminating liquid wastes.

ANIMAL PLANKTON: FOOD CONSUMERS.

Bacteria Eaters.—Let us next take up the consideration of the most important groups of animals which help to purify polluted water. Among the protozoa, which in comparison with the metazoa have the morphological value of a single cell, the colorless Flagellated Infusoria may be cited first as food consumers. By means of their small lashes, they direct minute particles of food, bacteria, etc., into their mouth-vacuoles which retain them. The numerous species of monads are thus typical bacteria-eaters, and in stagnant, putrefying water they often develop in extraordinary numbers. There are also many kinds of Ciliated Infusoria that eat bacteria. They are somewhat more highly organized than the preceding class, and usually have a mouth-aperture with a passage-way to the interior. With their cilia or their undulating membranes, they produce whirling currents in the surrounding water containing bacteria and other minute particles of food, including the flagellates just mentioned, whereby such bodies are brought into their vacuoles. These relatively large unicellular organisms thus dominate over the other living organisms in their vicinity, according to their size, like a cannibal among fish. Many of the Metazoa, including the Rotatoria, are likewise bacteria-eaters, and obtain their food in the same manner as the ciliates. Besides bacteria, this food material embraces other bacteria-eaters, diatoms, small Galæ, etc. If many bacteria-eaters are found in a water, it can safely be inferred that many bacteria are present, and hence also a quantity of putrefying substances, thus rendering a tedious counting of germs wholly unnecessary before expressing an opinion as to the sanitary quality of the water.

A great horde of lower animals is therefore striving incessantly to destroy the bacteria. If the latter disappear, the bacteria-eaters will also vanish, as they cannot find adequate subsistence in the purer water, and must either starve or become the prey of other animals. Heretofore it was believed that the bacteria died grad-

ually and were subject to a process of sedimentation; but if such were the fact, the beds of our streams would present a very different appearance. It is also highly improbable that an actual settlement of such extremely small organisms can take place in a stream having even a moderate current. Obviously some of the bacteria will be dragged to the bottom along with the heavy matter in suspension, but the great majority will not settle. Experiments in this direction have been made for improving the condition of the water in large aquaria and fish ponds by the precipitation of clay; but few have thought of the natural biological processes of water purification, because an unexpectedly extensive view of these processes has been gained only recently by planktological and thorough hydrobiological investigations.

Other Food Consumers.—Among the organisms that are carried in suspension in water, the minute Crustacea must also be considered. They are found in all seasons in the plankton of rivers, although in less quantity in swiftly-flowing streams. At one time the Cladocera, or water fleas, will predominate, while at another time the Copepoda will be the more numerous, according to their cycle of propagation. Their significance for the purification of water has likewise not been sufficiently appreciated. Concerning the quality of their food, numerous but not conclusive observations have been made. Some investigators assert that they live only on animal food, such as protozoa, while others claim that they use only vegetable food, such as diatoms and other minute algæ; but it must be remembered that both protozoa and minute algæ usually adhere to decaying detritus of animal and vegetable origin.

An enormous multiplication of Daphnia has been observed in highly-polluted village ponds, in which, however, various oxygen-producing algæ, and especially the euglena previously mentioned, rendered respiration or breathing possible. The question is, what becomes of the great quantities of offal and excreta, the many remnants of decaying plants, the refuse of communities, and the finely divided factory wastes of every description, which find their way into our streams, even under normal conditions, if a large portion thereof is not consumed by the aquatic detritus-eaters and the omnivorous fauna before settling to the bottom. By increasing the discharge of sewage into a river, a very large increase in the number of water-fleas has resulted, as was observed at Hamburg and elsewhere; and because the substantial value of the crustacea is materially greater than that of the rotatoria, the production of living animal substance is greater at all times in the sewage-polluted portion of the river than in the clean-water portion. Most of the larger crustacea are omnivorous, and many of them do not spare even their own progeny.

Food for Fish.—In addition to the bacteria-eating and omnivorous animals cited, there are many other species, especially rotatoria, and large ciliata, which feed preferably on algæ, as their digestive cavities are frequently found stuffed with green algæ and brown diatoms. All of these minute animals, and particularly the small crustacea, are of importance as food for fishes, and chiefly for young fish. After consuming the contents of their egg sacks, the latter take for their first food the very small animalcules, such as rotatoria and young crustacea; as their size increases, they feed on full-grown crustacea, and so on until they finally become the prey of larger fishes. The plankton thus forms the beginning of the cyclical course of matter for a fish.

Carp can feed exclusively on plankton crustea until they attain a weight of one pound. The putrescent matter that finds its way into our waters is thus transformed into useful fish-flesh; and from the relations of the interchange of matter between the plant and animal, it becomes evident that a certain degree of pollution of a stream is necessary from the point of view of social economy.

In the plankton of ponds, the animal components usually preponderate over the plants; hence we find that the slower the current of a stream, the more closely does its plankton agree in composition with that of a pond, and the algæ that cause "water blooming" are then also found more plentifully. In rapidly flowing streams, on the other hand, all forms of organisms are less abundant, and the maintenance of the purity of the water depends more on the attendant physical factors than on the plankton. This is confirmed by all the examinations of streams that I have made in various parts of Germany; and especialy was such, the case in the Rhine, which contains lilttle plankton and some of its tributaries, also in the Danube and other similar large rivers, in contradistinction to the more sluggish rivers Spree and Dahme, the latter of which is very rich in plankton and decomposable organic matter throughout the entire year.

It may also be said that the greater the quantity of impurities reaching a stream, the stronger will be the development of the plankton, and the greater the amount of work it will have to perform by means of its nutrition and growth. Nature always endeavors to help herself. The supply of fresh matter and organisms is obviously essential to the renewal of the plankton of a stream, and both of these are derived from coves, abandoned channels, and tributary ponds and lakes, many of which occur in the drainage areas of the rivers Spree and Dahme, for example. In the plankton of the waters of the Zoological Garden of Berlin, which are diverted from and returned into the Spree, I round in a single year more than 200 species of organisms, which led me to describe these park waters as culture tanks for numerous kinds of algæ that are capable of keeping the water clean throughout the entire year.

To be continued.

Electric Furnaces of the Induction Type*

Electrical and Metallurgical Features, With a Summary of Costs

By C. F. Elwell

ELECTRICAL FEATURES

THE furnaces for the refining of steel electrically, which have passed the experimental stage, may be divided into two distinct groups—namely, arc furnaces and induction furnaces. To the former belong the Heroult, Stassano, Keller and Girod furnaces, and to the latter the Kjellin and Röchling-Rodenhauser furnaces. Of the former the Heroult Furnace is perhaps the best known and most successful, and as comparison always carries more weight than a description it will be used as the representative of the arc furnaces. The electrical features may be divided up under several heads.

Distribution of Heating Effect of the Current.

Arc Furnaces.—In the Heroult Furnace the current passes from one electrode through an arc to the slag, through the slag to the upper metal, and thence through another arc to another electrode; and of the current which passes through the carbons only a small percentage passes through part of the metal. As the heating effect of the arc is far greater than any effect of the resistance of the charge, there must be large differences of temperature between different parts of the bath of metal, even in spite of the great activity of the bath around the electrodes. This is especially the case with a deep bath of metal. It is for this reason that Giron employs a bottom electrode, thinking thus to have these differences of temperature less by passing all the current for the arcs through the bath. From figures given in *Stahl und Eisen* for a 2-ton Girod Furnace, it was computed that the resistance of the carbon electrode was 3,800 times that of the bath of metal and so 3,800 times more electrical energy was converted into heat in the carbon electrode than in the bath itself. From this it is seen that if the current in the bath of metal produces any considerable part of the heat of the furnace, there must be a large loss of energy in the carbon electrode. The only correction for this is to make the electrodes larger, and the working limit has already been reached. The fact is that the bath is very little heated by the passage of the current and almost all the heating in this type of furnace is done by the very localized heating of the arc. The matter of the losses of energy in the carbons will be taken up under the heading of efficiency.

Induction Furnaces.—The principle of the induction furnace is already well known, but in order to compare the Kjellin and Röchling-Rodenhauser types it will be well to repeat briefly the principle of operation and the type of construction of the Kjellin type. The furnace consists essentially of an iron core around one leg of which is wound a primary winding inclosed in a refractory case and usually cooled by means of forced draft. The annular hearth surrounds this primary coil, and is separated from it by means of refractory material. This hearth contains the metal and acts as a secondary winding of one turn. The voltage induced in this turn is small, so that the energy transformed from the primary coil results in a very large current in the secondary, which heats the metal and thus nearly all the electrical energy is converted into heat in the metal to be melted. The ring being of constant cross section, the heating is about uniform over the whole bath of metal. The Röchling-Rodenhauser Furnace, which has a differently shaped hearth, is constructed either for single or three-phase current. In the former case there are two grooves, and in the latter three grooves. In both cases these grooves, which are similar to the grooves in the Kjellin Furnace, open into a distinct open hearth. The cross section of the grooves is comparatively small, and they form the secondary circuits in which the currents which heat the metal are induced. Lateral doors are provided so that the contents of the working chamber may be watched, slag drawn off or charge put in. The chief electrical difference between the Röchling-Rodenhauser and Kjellin Furnace is that a distinct secondary winding is provided in the former, and the current induced is led by means of heavy terminals to plates imbedded in the refractory material of the furnace. This refractory material becomes an electrical conductor at the higher temperatures, and this enables an additional circuit to be formed, so that the currents induced in the secondary winding pass through the bath of metal, heating the bath still further. The current also serves to neutralize the great self-induction of the secondary, and a better power factor is obtained. The point to be recognized here is that the heating is uniform and not localized as in the Heroult Furnace.

Variation of Load on Supply Mains.

Arc Furnace.—The instability of an arc is well known, and the load on a supply circuit, even with constant watching, varies very greatly. If the furnace has its own generator the regulation can be effected more simply, but the best furnace is one which can be connected to regular three-phase supply mains. To do so with the Heroult Furnace means motor driven electrode regulators, etc., and even then the furnace is not a very desirable load.

Induction Furnaces.—The changes in load on an induction furnace are always of the international kind and sudden changes of load are practically impossible with an induction furnace.

Adaptability to Connection to supply Mains

In the question of power factor the Heroult Furnace shows some advantage over the Kjellin Furnace, for in order to build a Kjellin Furnace of 8-ton capacity and keep the power factor up to 0.6 or 0.7 it was necessary to lower the frequency to five periods per second. As a 5-cycle generator costs more than twice as much as a 25-cycle generator this is a serious question. But with the Röchling-Rodenhauser Furnace the current in the second secondary winding can be used to neutralize the effect of self-induction to such an extent that a 7-ton furnace may be operated with 25 cycles with a power factor of 0.6, while a 3-ton furnace on 25 cycles has a power factor of 0.8. The smaller Röchling-Rodenhauser Furnaces are operated from 50 cycles with power factors of 0.85 and 0.8. In my opinion the most economical way to correct this evil is by using fixed condensers which cost only a small percentage of the cost of the furnace and the power factor may be made as high as desired.

Electrical Efficiency.

Arc Furnaces.—The before mentioned Girod Furnace with but one electrode of 14 inches, 35.6 centimeters diameter and a current of 6,200 amperes at 60 volts showed a power loss of 10 per cent in the electrode alone. In the Heroult Furnace the current is in general smaller, but there are two electrodes in series, and the result is about the same. Not only is energy lost in the electrodes by reason of their high resistance, but a large amount is also lost by means of the water cooling of the jackets, which is necessary because of their high conductivity for heat. The cost of maintenance of carbon electrodes is also considerable. Radiation loss is greater with the arc furnaces because a great deal of the heat of the arc is reflected to the roof, which must be water cooled to last, and even then has to be renewed about every 14 days.

Induction Furnaces.—Tests made on a 3.5-ton furnace at Volklingen have shown an electrical efficiency of 97 per cent, which is a contrast to the 10 per cent lost in electrodes alone in arc furnaces. The electrode plates never wear out for they do not come in contact with the molten metal or slag, and the portion of the lining which acts as a conductor has been found in practice to last longer than any other portion of the lining .

Summary of Electrical Features.

a. Heating of metal bath is much more uniform in induction furnace.

b. The variation of load is much less with the induction furnace.

c. The adaptability to connection to existing power networks is in favor of the induction furnace.

d. The efficiency is in favor of the induction furnace.

METALLURGICAL FEATURES.

The earlier induction furnaces, i.e., those of the Kjellin type, did not show many metallurgical advantages except that it was possible to treat much larger charges than with crucible methods. They were quite unsuited to working with slag because of the shape of

* Reprinted from the Proceedings of the American Institute of Electrical Engineers. A paper prepared for the Pacific Coast meeting of the Institute at Los Angeles, Cal.

the hearth, and so only served to melt pure materials. The shape of the Röchling-Rodenhauser Furnace is such that slags can readily be handled and refining carried on. At the same time it can be used for smelting work whenever necessary, and as much larger charges can be worked, a considerable saving is made in crucible steel working. The advantages of the electric furnace are:

1. On account of the convenient regulation of the temperature attainable the phosphorus can be removed until only a trace remains.

2. It is especially suitable for the most thorough desulphurization.

3. When the refining is complete, the charge can be left in the furnace as long as may be desired without change of composition.

At Trollhattan, Sweden, the furnace is started by means of a ring of metal. The cold materials are charged gradually until all are melted. Continuous operation is possible by leaving a portion of the molten metal in the furnace after each teeming. At Volklingen, Germany, the furnaces are supplied with molten metal from basic Bessemer converters, which contains about 0.08 per cent S and 0.08 per cent P. The extent of the dephosphorization and desulphurization depends on what the steel is wanted for.

An oxidizing slag is formed from lime and mill scale or ore, which is removed, as far as possible, when dephosphorization is complete. The recarburization takes place and a slag free from iron is formed for desulphurization. A typical slag for desulphurization has a well-known white appearance and falls to a white powder on exposure to the air. When the slag has this property the charge may be left as long as desired in the furnace. The furnaces are entirely emptied after each charge, as the molten converter steel allows the load to be readily brought to a satisfactory figure.

When not working about one-third of the normal energy will keep the furnace hot. The 7-ton furnace at Volklingen has been 30 hours without taking any current and was heated up again with normal energy consumption. Within half an hour the metal began to glow and regained its normal temperature after 4 hours and the charge was finished up in the regular way. At the works at Volklingen no work is done on Sunday, but there is no difficulty in starting up the furnaces with unfinished charges from the previous Saturday.

The natural circulation which takes place in induction furnaces serves to thoroughly mix the charge, and the management of the Poldihütte, Austria, made a test in which seven samples were taken from six different places in the furnace and the analysis of these samples is shown in the following table:

	Carbon, Per Cent.	Manganese, Per Cent.	Silicon, Per Cent.	Phosphorus, Per Cent.	Sulphur, Per Cent.	Chromium, Per Cent.
1	0.81	0.27	0.335	0.021	0.007	1.00
						1.01
2	0.77	0.25	0.340	0.030	0.008	1.00
						1.01
3	0.85	0.28	0.345	0.029	0.007	1.00
						1.01
4	0.82	0.27	0.335	0.030	0.009	0.98
						0.99
5	0.78	0.25	0.335	0.030	0.009	0.99
						0.96
6	0.78	0.27	0.419	0.031	0.010	0.99
7	0.79	0.28	0.326	0.030	0.009	0.98

The furnace was teemed 37 minutes later, and a sample cast-out of the ladle gave the following analysis:

	Per Cent.
Carbon	0.77
Manganese	0.29
Silicon	0.396
Phosphorus	0.031
Sulphur	0.009
Chromium	0.99

That the Röchling-Rodenhauser Furnace is no longer an experiment is shown by the fact that the 3.5-ton furnace was worked for a whole year producing steel for rails, and more than 5,000 tons have been sold. The 8-ton furnace has been running since November, 1908, an average of 14 days to a lining and 1,200 tons of rails to a lining. The management contemplates the building of a 16-ton furnace as the next step. At Dommeldingen the 2-ton furnace is used to refine crude pig iron. The chemical and physical properties of the metal are given below:

	Analysis of Charge, Per Cent.	Analysis of Cast, Per Cent.
Carbon	4.0	0.50
Phosphorus	1.8	0.025
Sulphur	0.2	0.03
Manganese	0.0	0.76
Silicon	1.05	0.056
Breaking Strain	95,000 lb. per sq. in.	
Elongation	20 per cent	
Contraction of area	36.33 per cent	
Duration of conversion	5 hours	

Summary of Metallurgical Features.

1. Having no electrodes, facilities are provided for heating the bath without introducing impurities and the charge may be left indefinitely in the Röchling-Rodenhauser furnace without change.

2. Having a large open hearth (in the 1.5-ton furnace it is 60 × 26 inches or 1.52 × 0.65 meters), with doors it is possible to do any class of refining in the Röchling-Rodenhauser furnace much the same as in the open hearth furnace.

3. When the hearth doors are closed the Röchling-Rodenhauser furnace is air-tight and may be left for long periods without great loss of heat, making intermittent working possible.

4. The natural gentle movement of the charge allows of complete mixing of the ingredients of the charge, and is not sufficient to attack the lining.

COSTS OF PRODUCTION.

Royalty: The German users of the induction furnace pay $0.65 per ton for rail steel and $1.50 per ton for crucible quality steel. This is for small daily production. For 1,000 tons daily the royalty is placed at $0.36 per ton for rail steel and for 1,200 tons daily it is $0.50 for crucible quality steel.

Energy Required: A great many figures have been given out, most of which were for small furnaces and special runs. The plants at Trollhattan and Volklingen being in commercial operation supply the most reliable figures obtainable.

Cold Pig and Scrap: With cold materials, refining, etc., to crucible quality steel is done with 600 to 900 kilowatt-hour per ton according to the size of the furnace.

Hot Pig and Scrap: With hot pig iron and cold scrap crucible quality steel is obtained with 300 to 700 kilowatt-hour per ton according to the proportions of the two ingredients and the size of the furnace.

Hot Metal from the Converter: Converter material with an analysis of P, 0.08 per cent; S, 0.08 per cent; Mn, 0.5 per cent; C, 0.1 per cent is refined to steel for rails with an analysis of P, 0.05 per cent; S, 0.04 per cent; Mn, 0.85 per cent; C, 0.5 per cent with 100 kilowatt-hour per ton in a 7-ton furnace. Some material is refined to high quality steel showing only traces of P and S; Mn, 0.2 per cent; C, 0.5 per cent, with 250 kilowatt-hour per ton.

Hot Metal from Open Hearth Furnace: Material from open hearth furnace, already dephosphorized and desulphurized and containing 1.22 per cent C; Mn, 0.38 per cent; Si, 0.21 per cent to high quality steel with 200 to 250 kilowatt-hour per ton

1. Cost with a 1 5-ton furnace melting scrap and refining to pour best steel for steel castings.—Furnace of the three-phase, tilting type. 50 cycles, 210 kilowatts and power factor 0.80.

Interest Charges: Cost with all accessories about $9,000. With 10 per cent for interest charges gives $900 annually. Using 290 working days in a year and six charges, 3 to 3 5 hours each, daily and 1,500 pounds to a charge gives 4.2 tons daily and 1,220 tons yearly. This is equivalent to about 21 hours working. Cost per ton for interest, $0.74.

Labor: Two men can attend to this furnace with ease, as the electrical part requires no special attention. The melter adjusts the temperature and watches the metallurgical process. The helper sees to the fan and charging, etc. Allowing two shifts and $5.50 per shift or $11 daily gives a labor cost of $2.62 per ton of steel.

Lining: Relining may be done every 8 or 14 days. It takes three tons of magnesite and 0.36 ton of tar to completely reline the furnace. The relining is done with half new material and half old. For getting out the old lining, mixing material and putting in the new, four men are allowed 16 hours. Cost of lining per ton of steel, on an average, $1.50

If lined with dolomite, which is cheaper, and every 14 days, then lining cost, allowing one-third material recovered, is $1 per ton of steel.

Keeping Warm: When the furnace is not used for several hours during the night it must be kept warm, for which about a third of the working amount of energy is necessary. In this way if normal energy is 200 kilowatts then about 200 kilowatt-hours will be necessary to keep the furnace warm over the three-hour period of rest. For six working days this is necessary five times and 1,000 kilowatt-hours must be charged up to heating. Cost of keeping furnace warm at $20 per kilowatt-year is $0.09 per ton of steel.

Cooling of Transformer: The blower takes a 2.5-horsepower motor or 1.8 kilowatts and for 24 hours = 43 kilowatt-hours. Cost of cooling per ton of steel, $0.02.

Energy Consumption: From cold materials about 850 to 900 kilowatt-hours are necessary, in this size furnace. Taking larger figure the cost of energy per ton is $2.06.

Royalty: In the United States, a plant of 50 tons daily royalty would be about 50 cents per ton.

Summary of Cost.

Interest Charges	$0.74
Labor	2.62
Lining	1.50
Keeping furnace warm and cooling	0.11
Royalty (approx.)	0.50
Energy for melting and refining	2.06
Total	$7.53

The figure $7.53 is the working cost which must be added to the cost of the materials in order to find the cost of crucible quality steel from scrap. The above figure would be more reasonable with larger furnaces.

2. Cost with a 2-ton, 300-kilowatt, three-phase tilting furnace.—Molten converter steel to quality steel for castings.

Cost with all accessories about $12,500. With 10 per cent for interest charges gives $1,250 per annum. Allowing 250 working days in the year and 16 tons per day gives 4,000 tons per annum, or $0.31 per ton of steel.

Interest charges per ton of steel	$0.31
Power for heating up, per ton of steel	0.02
Power for refining, allowing upper figure of 300 kilowatt-hour at $20 per kilowatt-year	0.68
Air cooling of furnace core	0.01
Cost of lining every 10 days (German figure)	0.35
Wages, allowing $16 per day	1.00
Royalty on basis of 50 tons daily	0.50
Total cost per ton of steel	$2.87

This figure would give a good idea of the cost of converting molten pig iron into steel, exclusive of the ferro-alloys.

3. Cost with a 5-ton, 550-kilowatt, three-phase tilting furnace.—Molten converter steel to crucible quality steel.

Cost with all accessories about $22,000. With 10 per cent for interest charges gives $2,200 per annum. Reckoning 250 working days in the year, each one with eight heats of 5 tons, the yearly production would be 10,000 tons, or $0.22 per ton for interest charges.

Interest charges	$0.22
Power, including heating up. For a monthly average of 230 to 280 kilowatt-hours per ton and taking the higher figure	0.64
Cost of lining (German figure)	0.30
Wages, allowing $20 per day	0.50
Air cooling of core	0.01
Royalty (approx.), basis of 50 tons daily	0.50
Total	$2.17

4. Cost with a 7-ton, 750-kilowatt, three-phase 25-cycle, 0.6-power factor tilting type furnace.—Converting molten converter steel into high grade rails.

Cost with all accessories $27,000. Interest charges at 10 per cent gives $2,700 per annum. Allowing 100 tons daily (the makers claim a production of 140 tons) and 250 working days in the year gives a yearly production of 25,000 tons of rail steel and interest charges per ton of steel equals $0.11.

Interest charges	$0.11
Power for heating up	0.01
Power for refining. Makers claim 100 kilowatt hours per ton. Allowing 150 kilowatt-hours per ton	0.34
Power for cooling	0.01
Cost of lining. Pneumatically tamped. Two foreman and six laborers, or $21 daily. Per ton.	0.02
Cost of lining material (German figure)	0.06
Wages. Two head melters at $3 and 10 helpers at $2.50 $31 per ton	0.31
Royalty on rail steel, one furnace in U. S.	0.35
Total	$1.21

This is the conversion cost, which added to the value of the pig and ferroalloys, etc., gives the cost of steel for rails. The Prussian railroads paid $10 extra per ton for rails made in this furnace and were well pleased with the product.

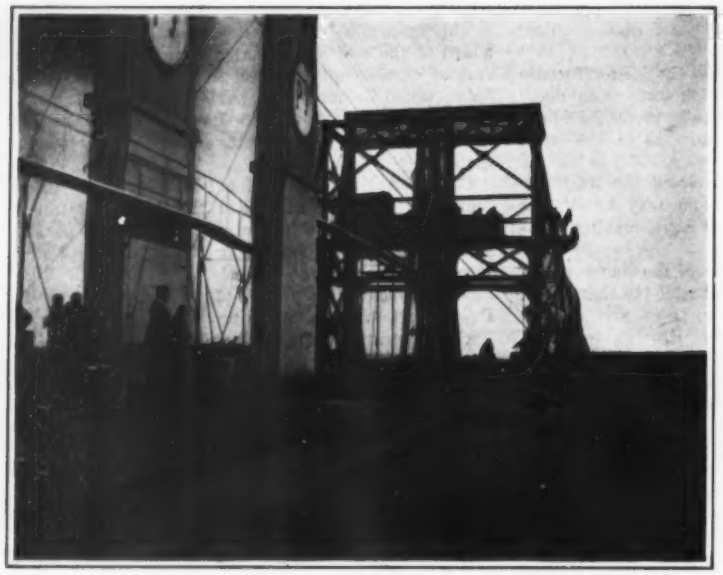
5. Cost with a 7-ton, 750-kilowatt, three-phase, 25-cycle, 0.6-power factor, tilting type furnace.—Molten converter steel to highest quality steel.

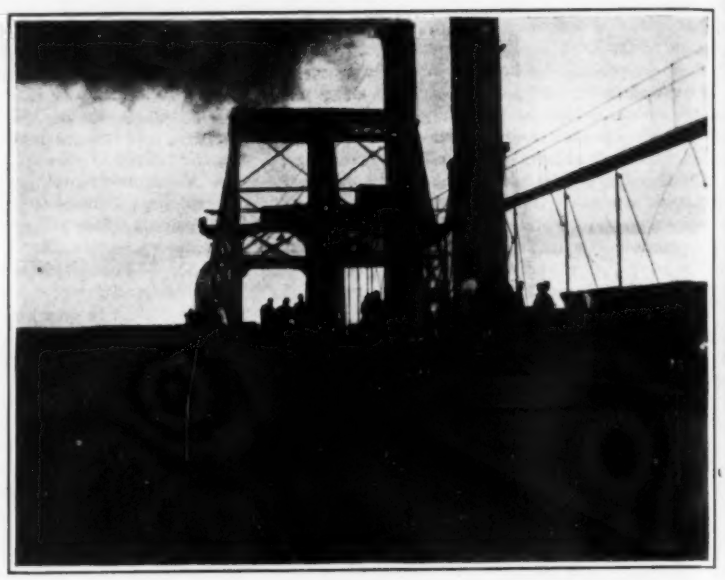
This furnace will produce about half the steel of this quality as when working on rail steel, or 50 tons daily. The cost per ton under these conditions is about $2 per ton, including royalty.

Summary of Costs of Production Exclusive of Materials.

1.5-ton furnace melting scrap and refining to pour high grade steel for castings. Per ton	$7.53
2-ton furnace refining molten converter steel to high grade steel. Per ton	2.87
5-ton furnace refining molten converter steel to high grade steel. Per ton	2.17
7-ton furnace refining molten converter steel to high grade steel. Per ton	2.00
7-ton furnace refining molten converter steel to high grade rails. Per ton	1.21

London-Amsterdam Telephone.—The British Post Office has lately been experimenting in telephone communications between England and Holland. The London correspondent of the *Amsterdam Telegraaf*, on invitation of the post office authorities had conversations with Amsterdam and Rotterdam, and found that he could hear very distinctly. Those experimenting on the other side, also expressed satisfaction with the result. The postmaster-general, according to the London *Times*, hopes to be in a position to open an Anglo-Swiss telephonic service as soon as the negotiations with the Swiss and French administrations have been completed.





A Large Railway Ferry Steamer for the Volga

A Boat Designed for Service Under Peculiarly Difficult Conditions

By F. C. Coleman

An extremely interesting railway ferry steamer for Russia, constructed at the Walker shipyard of Sir W. G. Armstrong, Whitworth & Co. (Limited), of Newcastle-on-Tyne, England, to meet conditions which are very unusual and difficult to comply with is illustrated in the engravings. The river Volga, across which the ferry is to ply, is very swift, and the difference between the extreme levels of midsummer and spring is no less than 45 feet. The embarking and disembarking of the rolling stock, of course, becomes a question of considerable difficulty, and when to this is coupled the fact that unbroken communication has to be maintained between the two sides of the river, although ice of 2 feet in thickness is in winter rather the rule than exception, the problem assumes rather serious proportions. A powerful steam ice-breaker was ordered for the purpose of making and keeping open the channel in which the ferry plies. This vessel, which was also built by the firm named above, was despatched some time ago. The locks of the Marinsky Canal system, through which all vessels bound for the Volga must pass, are of such dimensions that it was necessary to divide both the ice-breaker and the ferry steamer—the former into two, the latter into four parts. This has been accomplished on Swan's patent system, which allows the division and subsequent reunion to be effected while the vessel is afloat. The principal dimensions of the ferry steamer are: Length 252 feet, breadth 55 feet, 6 inches; depth 14 feet, 6 inches. Four lines of rail are laid which converge at the fore end into two, and sufficient space is provided on the rails for twenty-four trucks. The difficulty presented by the enormous difference in the river level has been overcome by an arrangement of hoists, actuated by hydraulic cylinders. This structure is placed at the bow of the vessel and is so designed that two trucks can be lifted at once. The cradles, two in number, are flush with the deck when in the lowest position, the trucks are hauled on to them by means of an hydraulic capstan, and can be lifted to a height of 25 feet. The landing stages on both sides of the river are of wood, and have lines of rails at two stages, so that with the range of 25 feet given by the hoist, the difficulty of the 45 feet change of level is entirely overcome. The pressure for the hoists is supplied by two horizontal compound direct-acting pumps, situated in the engine-room, and connected by an arrangement of piping to the lifting cylinders. The pipes and connections, which are all designed for a working pressure of 750 pounds are coupled direct to the lifting cylinders without the interposition of accumulators, and are so arranged that either pump can be connected to either or both of the lifts.

Special means have been employed to guard against the possibility of the water in the pipes and cylinders becoming frozen in the extremely low temperature experienced in the Volga in winter. The deck of the ferry steamer, is, of course, flush, and as all the deck space is

Steaming Down the River.

required for the accommodation of the railway trucks, the cabins for the captain, officers and engineers have been placed forward under the deck, all the rest of the space, with the exception of two holds, being taken up by the propelling and lifting machinery. Advantage has been taken of in the framing of the hydraulic hoists to make a large navigating bridge, with wheelhouse and all the usual appliances, and to afford support to the searchlight. A gangway above the level of the tops of the carriages, besides providing a convenient passage for the officers from one end of the ship to the other when all the rolling stock is on board, enables them to direct the operations of embarking and disembarking The propelling machinery, which is of the inclined twin-screw compound surface-condensing type, has been skilfully arranged in the rather small space allotted for its accommodation. The clear height is very small, which rendered inclined engines and boilers of the straight type, or "Navy" type, a necessity. All the necessary arrangements are made for burning liquid fuel, and the burners present one or two features of great interest. The propellers are of bronze and are made of extraordinary heavy scantling, so as to enable them to resist the blows they will encounter in their service among loose ice, some of which will be of great thickness. The way through the ice will be cut as already described by the steam ice-breaker, so that the ferry steamer will not, as a rule, be called upon to do any actual ice-breaking. The strength of her hull is, however, proportioned to resist great shocks, and the bow is amply strong enough to break ice to a certain extent, although the form of the boat was evolved to meet a set of circumstances of which ice-breaking does not form the most important item. The division of the ferry steamer into four parts has been carefully thought out, with the result that each quarter is a water-tight hull, bounded by the half length of the shell on one side and one end, and by longitudinal and transverse water-tight bulkheads on the other, and is so arranged that the four portions can be separated and connected while the vessel is afloat. The trim of these quarters was a somewhat delicate matter to arrange, and one to which the distribution of the weight does not easily lend itself. It was found necessary to make pontoons, which will be attached to each quarter of the ferry steamer, and by this means the required trim and draft will be attained, when the division of the hull into four parts has been effected. Speed in a vessel of this description is a somewhat secondary consideration, especially as the propellers have to be designed more with a view of resisting blows than of attaining a high efficiency. The performance in this respect, therefore, was eminently satisfactory, as a speed of over nine knots was easily maintained. The general appearance of the vessel is well shown in our frontispieces, one of which is a side view, and another a view along the deck.

A Gasoline Switching Locomotive

Our illustration shows a 50 horse-power switching locomotive used in the Union Pacific Railway. It is operated by a gasoline motor of the three cylinder type. This locomotive has a total weight of 24,000 pounds and a length over all of 21 feet 11½ inches, its width over all being 7 feet. It is designed for a standard track of 4 feet 8½ inches gage. On low speed at 350 revolutions per minute the locomotive makes 4 miles per hour and on high speed the locomotive makes 8 miles per hour. It has a tractive power of 4,000 pounds and the diameter of the cast iron driving wheels is 33 inches.

The locomotive is housed with a sheet steel cab, provided with windows and doors which give the operator unobstructed view in all directions. The power is supplied by a gasoline engine of the inclosed crank case type developing 50 horse-power. The 3 cylinder air-starting and reversible engine can also be started by cranking as in automobile practice. The cylinders are 8 inches by 10 inches and are water-cooled, while he crank shaft is of carbon steel.

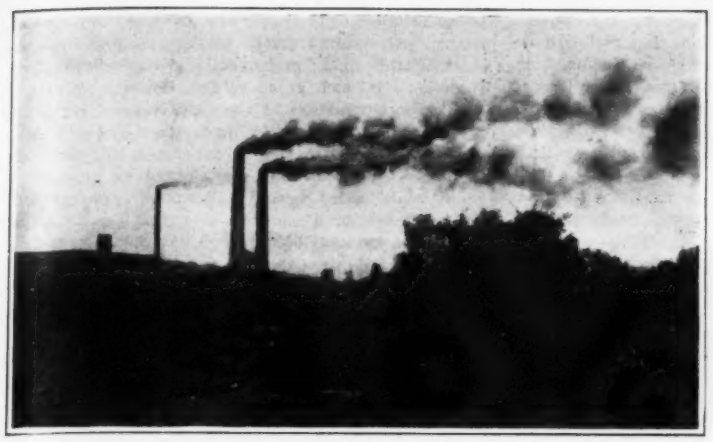
In tests the engine has developed a maximum of 75 horse-power, the normal output being 50 horse-power. This gasoline switching locomotive is driven

Gasoline Locomotive.

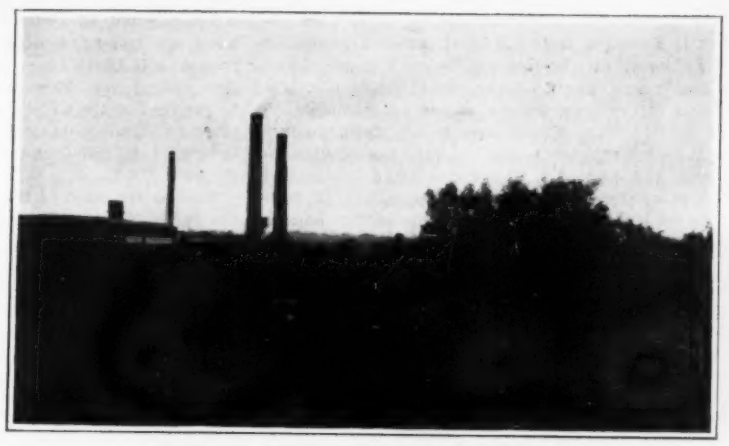
by the motor through a cone clutch, and by means of a Morse silent chain, the power being transmitted to both axles through bevelled gears.

It is pointed out that high and low speed gearing is available for use in both directions. The speed changing device consists of a three-jaw sliding clutch, and the lower transmission shaft is equipped with universal joints to take care of the alignment of the shaft under the varying track conditions. The clutch operating levers are located close to the engine so that the motorman can easily reach from his seat all levers for operating the car, brakes and engine.

Compressed air is used for the whistle as well as for starting the engine and operating the brakes, the air being supplied by a pump driven by the motor. The air supply is carried in steel tanks secured in the frame of the locomotive and is connected with the necessary piping. The engine is water-cooled, the circulating system consisting of a rotary circulating water pump and cooling coils located on the roof of the locomotive as seen in the photograph.



The Stacks of the Knoxville Railway & Light Company, Showing the Habitual Appearance Before the Installation of the Smoke Consumers.



The Same After the Smoke Consumers were Installed Fuel Saving, 15.8 Per Cent.

Economic Aspects of the Smoke Nuisance*

Chimneys Need Not Be "Smokestacks"

By Prof. John A. Switzer

So ACCUSTOMED have we become to the sight of dense columns of smoke proceeding from the chimneys of factories, that to many of us this has come to be regarded as an inevitable accompaniment of the burning of soft coal. This belief is attested by our usual name for chimneys—we call them smokestacks, thereby implying that the office of the stack is to make smoke. Very recently we have come to know that the issuance of a column of black smoke from a chimney is a positive indication that in the furnace below coal is being wastefully burned. It is not yet, however, a matter of sufficiently common knowledge either that the smoke can be in large part eliminated or that its elimination can be made a matter of substantial profit to the factory owner.

It is the purpose of the present paper to offer proof in support of the assertion that smoke abatement is a measure of such economy that no manufacturer can afford to ignore its claim upon his personal consideration.

Such proof could be obtained from many different sources; but the writer prefers to confine himself to instances which have come under his personal observation, and for the reliability of which he can vouch.

During the years 1910 and 1911 four sets of boiler trials have been made by the Department of Mechanical Engineering of the University of Tennessee for the specific purpose of studying the economic relations of smoke abatement.

The first of these was a study in methods of handling furnaces, and the tests, two in number, were made in the power house of a large cotton mill near Knoxville. The boiler equipment of the plant consists of four 200-horse-power continental boilers of the Morrison Scotch marine type, served with Hawley down-draft furnaces. Natural draft is obtained by means of a chimney 152 feet high, and draft is controlled by an automatic damper. The power required of the plant was between 600 and 700 boiler horse-power, and this was furnished by three of the boilers, the fourth being held in reserve.

The claim is made for the Hawley down-draft furnace that it is a smokeless furnace; and while I know of plants where this claim is borne out, the plant in question made a great deal of smoke. Preliminary observation convinced us that at least a part of the smoke could be attributed to the methods of the fireman. Consequently, with the hearty co-operation of the mill superintendent, two boiler trials were conducted, on successive days.

Throughout the first test the fireman handled his furnaces in his accustomed manner. His method was to fire at comparatively long intervals, to fire large quantities of coal at a time and occasionally to "understoke," that is to fire green fuel upon the lower set of grates. He explained to the writer that he could not "hold steam" unless he did this, although the practice is contrary to the instructions received from the makers of the furnace. The day of the second trial chanced to be stormy, and was so dark that the electric lights throughout the mill were burning nearly all day. This increased the load upon the boilers and made the furnace management correspondingly more difficult. The load during the first day was 647 boiler horse-power and during the second, 690.

During the second trial coal was fired frequently and in small quantities. No green coal was fired upon the under grates, and care was had not to shake coal down from the upper grates until after the volatile matter had been distilled from it. Other than this, conditions were maintained alike for both tests.

The boiler feed water was weighed in tanks; coal was weighed in wheelbarrows, and the other measurements contributing to complete boiler trials were made in the usual manner known to mechanical engineers. Throughout both tests smoke observations were made

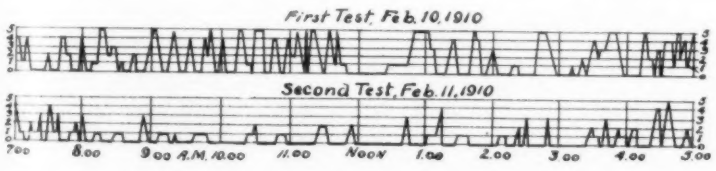


Fig. 1.—Ringlemann Smoke Chart of Boilers of Cotton Mill. Representing a Saving of $835.00 Per Annum in Favor of Smokeless Furnace.

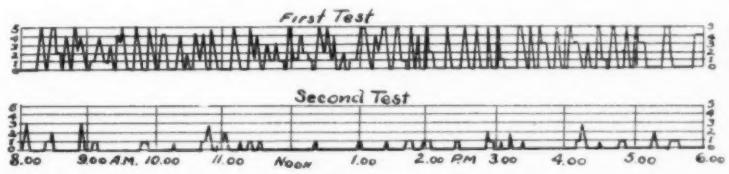
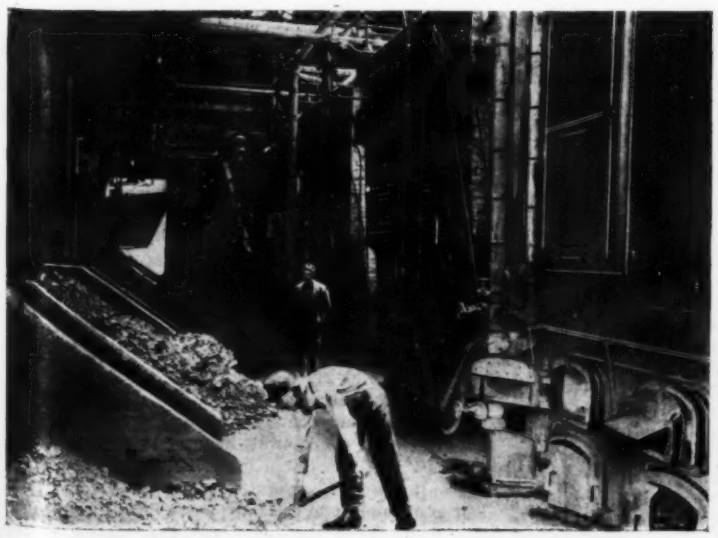


Fig. 2.—Ringlemann Smoke Chart of Test of Boiler at University of Tennessee. Representing a Fuel Saving of 16.2 Per Cent.



General View of Boiler Room, Knoxville Railway & Light Co.

One of the 600-Horse-power Babcock and Wilcox Boilers, Knoxville Railway & Light Company. Types of Boilers Used in Experiment.

* Reproduced by courtesy of the Editor of The Resources of Tennessee.

by the Ringlemann chart record. To do this an observer is stationed, watch in hand, where a good view of the chimney may be had, and before him are placed the Ringlemann charts. These, six in number, consist of cards, of varying degrees of blackness, numbered from zero to five. Number five is jet black, number four is 80 per cent black, number 3, 60 per cent; 2, 40 per cent, and number 1, 20 per cent black, while card No. 0 is entirely white. At the expiration of each minute the observer records the number on this Ringlemann scale, corresponding to the density which the smoke has exhibited during the minute. The records are then plotted on cross section paper so that a visual comparison of the plotted charts gives a fairly clear impression of the relative qualities of smoke emitted.

Fig. 1 shows the smoke charts made during these two tests. Only once during the eleven hours of the second test did the smoke reach No. 5 blackness, and then only for a single minute, whereas during the first test No. 5 smoke was of frequent occurrence, and it is evident that the better furnace management resulted in eliminating a large fraction of the smoke.

But the better furnace management resulted also in a very satisfactory saving of fuel. For the benefit of those having an interest in the technical details of the tests the principal data are exhibited below. To those not technically inclined, however, the most interesting fact is that the fuel-saving figures 13.1 per cent and this, on a basis of 310 working days per year, and coal costing $1.50 per ton laid down at the boiler room, and assuming an average power demand of 650 horse-power per day, represents in this instance a cash difference of $835 per annum in favor of the smokeless method of furnace management.

It was quite true that the work of the fireman was much heavier the second day than the first; but the fuel saving shown by the tests to be obtainable was such as amply to justify the superintendent in following either of two courses, either the fireman should be allowed a bonus for saving fuel or else a part of the possible saving should be used in hiring an additional boiler room attendant.

The principal data of the tests follow:

	First test.	Second test.
Duration of trial, hours	11	11
Steam gage, pounds	136	133.2
Draft gage, inches of water	0.45	0.42
Temperature flue gas (before passing economizer, degrees)	480	448
Temperature flue gas (after passing economizer, degrees)	352	336
Heat value of coal, B. T. U.	13,234	13,017
Total coal consumed, pounds	270.15	254.18
Total ash, per cent	12.7	11.4
Total weight apparent evaporation, pounds	234,856	249,934
Equivalent evaporation per pound of fuel from and at 212 degrees	9.22	10.44
Equivalent evaporation per pound of combustible from and at 212 degrees	10.54	11.80
B. T. U. supplied per pound of water evaporated	1,531	1,330
Boiler horse-power (34½ pounds equivalent evaporation per hour)	647	690
*Efficiency of boiler and grate per cent	67.5	77.5

While these tests illustrate the possibility of smoke abatement by means of more careful firing in a plant equipped with the Hawley down-draft furnace, by far the largest number of boilers are not so equipped; and with the ordinary type of grate more is required than careful stoking to attain to anything like smokeless combustion. There are a number of so-called smoke consumers on the market for attachment to the ordinary type of boiler setting. Most of these utilize steam jets to accomplish their purpose. The early reports that were published concerning the use of steam jets were not favorable to them; and believing that this was occasioned by the fact that the apparatus tested was not automatic, the mechanical department of the university was glad to accept from the G. H. Scharf Company, of Ypsilanti, Mich., a gift of an equipment for their own boiler plant, and to carry on careful tests of the equipment.

But one boiler was equipped with the apparatus—a 75-horse-power return tubular boiler.

To understand the principle on which the apparatus works, one must have a clear understanding of what takes place when coal burns under a boiler. Our ordinary bituminous coal is a very complex mixture of chemical compounds—it is not a single substance. A number of these compounds, containing hydrogen and carbon, and hence called hydrocarbons, are for convenience grouped together and are called the combustible volatile matter of the coal. The reason for this is that only a little heat is required to drive these compounds out of a lump of coal. They are colorless gases, and under favorable conditions they readily burn. Indeed it is these gases which comprise our ordinary illuminating gas. They constitute from 40 per cent to 55 per cent of the weight of our Tennessee coals. The other constituents in coal are moisture, fixed carbon, or coke, and ash; and besides these, a very little sulphur.

When a shovelful of fresh coal is thrown on the hot fire the hydrocarbons begin instantly to be distilled off in great volume and to burn. If conditions are right the gases will burn and no smoke whatever will ensue. But ordinarily conditions are not right. For the complete combustion of these large volumes of gas a correspondingly large volume of heated air must instantly be supplied and be mixed with them; but usually it is not. This results in the decomposition of a part of the gases with the consequent production of smoke, and of course loss of the heat, which would be generated if complete combustion took place.

Since these gases constitute so large a proportion of the weight of the coal, and since they require for their liberation in the furnace only a few minutes following the act of firing, it is clear that a chimney that pours forth a great quantity of black smoke constitutes itself a public notice that coal is being wastefully burned in the furnace below.

It is the office of the automatic steam jets to produce the necessary increase in draft at the time when the increased air supply is needed, and as the need gradually ceases the supply of steam to the jets is gradually diminished and at the proper time finally stopped. When the fireman opens his fire door to stoke, this act starts the steam jets to blowing, and at the same time lifts a damper in the fire doors, thus providing an avenue for the inspiration of air; and after he has closed the door a dashpot arrangement controls the closing of the dampers and the shutting off of the steam.

The tests of this equipment consisted not only in determining the boiler performance with and without the equipment in operation and making the usual smoke observations, but also in determining with considerable accuracy the amount of steam used by the jets themselves. Fig. 2 is a plotting of the smoke charts made during the progress of the two boiler trials; the upper curve during the trial without the "smoke consumer" in operation and the lower with it.

During the first trial the load was 59 horse-power; during the second, 79; the former being 80 per cent and the latter 105 per cent of the builder's rating. It is interesting to note that while without the smoke consumer the plant could not deliver 80 per cent of its rated capacity without dense black smoke, with it 105 per cent of the rated capacity was developed, practically without smoke.

The efficiency of the boiler during the first test was 52.6 per cent, and during the second, 62.1 per cent.

During the first test 6.7 pounds of water were evaporated per pound of coal burned, and during the latter 8 pounds; or in the former an equivalent evaporation (from and at 212 degrees) of 7.4 pounds, and in the latter of 9 pounds. Since the steam jets were found to use 4.6 per cent of the steam generated, 4.6 per cent of the 9 pounds of water should be deducted, leaving 8.6 pounds available for transmission from the boiler for useful work. The basis of comparison of boiler performances is, therefore, the 7.4 pounds equivalent evaporation, and the 8.6 pounds. And this difference represents a fuel saving of 16.2 per cent.*

The results of these tests led to the placing of orders for like equipment in two large power houses in Knoxville, and this afforded the Department of Mechanical Engineering of the university an opportunity to conduct tests at both of these plants to determine their performance with and without the equipment installed.

The first of these is the power house of the Knoxville Railway and Light Company. Here there are five 600-horse-power Babcock and Wilcox and three 300-horse-power Stirling boilers. Our lower illustrations show the boiler room, and a more detailed view of one of the large boilers, while the two headpieces show the stacks before and after the installation of the "smoke consumers." Before the installation was made, a photographer would have waited in vain—if he waited for a month—for an opportunity to get a picture similar to the lower one, for there never was a moment when black smoke was not issuing from one stack or the other; and usually it was pouring forth from both in such great volume that the column of smoke constituted one of the landmarks of Knoxville. Since the installation was made there are still times when dense black smoke is generated, but these are the times when fires are being cleaned, or when fire is being made under a cold boiler; and even at such times the volume of smoke sent out is less than that which was habitual before; and now for a large fraction of the time the chimneys show no smoke whatever.

The smoke consumers were put in under a positive guarantee (1) to abate 90 per cent of the smoke; (2) to increase the capacity of the plant 10 per cent; (3) to decrease the deposit of soot on the tubes 50 per cent, and (4) to save 10 per cent of fuel.

The guarantee was to be determined by two evaporative tests, to be made by the writer, and by the monthly records of coal consumption and of electrical output of the company itself. Since the latter are of more interest, they will be reported first. The coal consumption, the total electrical output for the month, and the number of pounds of coal consumed per kilowatt are here given for each month of the year 1910, and then since the smoke consumers were installed in April, 1911. The same data are presented for May, 1911. The records are as follows:

	Coal Consumed Pounds.	Kilowatt Hours Output.	Pounds of Coal per Kilowatt hr.
January	3,958,000	960,948	4.12
February	3,646,000	826,604	4.42
March	3,680,000	876,322	4.10
April	3,576,000	854,510	4.18
May	3,816,000	860,368	4.43
June	3,506,000	855,756	4.09
July	3,734,000	879,700	4.24
August	3,788,000	908,640	4.16
September	4,648,000	1,086,640	4.27
October	4,746,000	1,084,834	4.37
November	4,354,000	1,054,529	4.13
December	4,864,000	1,141,964	4.26
Average for 1910			4.24
May, 1911	3,356,000	939,000	3.57

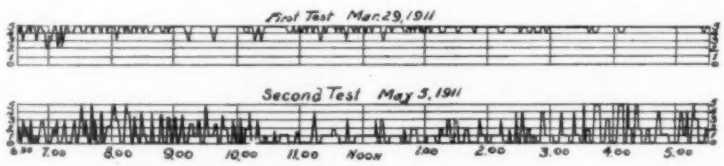


Fig. 3.—Ringlemann Smoke Charts of Tests of Knoxville Railway & Light Company's Plant. Saving in Fuel, 20.9 Per Cent.

On the showing of these records the fuel saving appears to be 15.8 per cent.

The fuel consumption for June, 1911, was 3.70 pounds per kilowatt hour; and although the fuel consumption for June, 1910, was lower than for any other month of that year, it is interesting to note that the fuel saving this June over last amounts to 29 per cent of the entire costs of the smoke consumers.

The two evaporative tests were made on March 29th and May 5th, respectively. Fig. 3 shows the two smoke charts obtained. Beside determining the evaporation and efficiency of the boilers, the electrical output was determined with great precision, so that a comparison of the two performances on the basis of the showing at the switchboard could be made. It should be explained that three of the 600-horse-power boilers suffice to carry the day load of the station, and four the "peak load." Prior to the installation of the smoke consumers it had been customary to build the fire under the fourth boiler at about 2:30 P. M., and this was done on the day of the first test. Since making the installation, however, it has been found that this may be deferred until 5:30 P. M. Consequently, on the day of the second test, but three boilers were under steam.

The detail of the tests will be omitted for the sake of brevity and the results only reported. These were as follows:

	First Test.	Second Test.
Pounds of water evaporated per pound coal	7.73	9.93
Heat value of coal, B. T. U.	13,528	13,091
Equivalent useful evaporation from and at 212 degrees	8.52	10.52
Efficiency of boiler and grate	60.8	77.8
Kilowatts per hour output	1,540	1,450
Pounds of coal per kilowatt hour.	4.38	3.56

On the basis of these tests the fuel saving would appear to be 19.4 per cent.

It is of interest to account for the difference between this figure (19.4 per cent) and that shown by the monthly records of the Railway and Light Company—15.8 per cent.

* Thesis of C. L. Brown, 1910.

* Thesis of Dempster and Stoltzfus, 1910.

Just prior to installing the smoke consumers, the company had equipped the battery of boilers with the Vulcan soot blowers. In order to eliminate any influence which the use of these blowers might have upon the two boiler performances, it was agreed by Mr. Link, the engineer of the station, and myself, that the use of the blowers should be suspended for a period of thirty-six hours preceding each test. The usual practice is to blow the soot from the tubes twice daily. Despite the non-use of the soot blowers the economy of the plant on the day of the second test, namely, 3.56 pounds of coal per kilowatt hour, was practically the same as that shown by the station records for the entire month, namely, 3.57 pounds, a remarkably close agreement. The non-use of the blowers for thirty-six hours prior to the first test had evidently left the tubes badly coated with soot, as was shown by the coal consumption of 4.38 pounds per kilowatt hour, which was higher than the average for the entire year 1910, namely, 4.24 pounds per kilowatt hour. Thus the two evaporative tests, while failing to yield a fair basis for calculating the fuel saving effected by the smoke consumers, furnished an unexpected proof of their efficiency in reducing the deposit of soot upon the boiler tubes.

When manufacturers generally come to understand more clearly the economic aspects of smoke prevention a great impetus will assuredly be given to the movement looking to the purification of the atmosphere.

The problems of smoke elimination have by no means all been solved. The most vexatious source of smoke in many cities is probably the railway locomotives. It yet remains for some genius to discover a method of burning soft coal in locomotive furnaces without smoke. But here more than anywhere else the care exercised by the fireman, or the lack of care, shows in the volume of smoke produced. Fifty per cent of the smoke made by a careless fireman can be obviated by the enlightenment of the fireman. When this fact is realized our cities can at least demand of railways that they make their minimum of smoke. Furthermore, the cities would be well within their rights were they to demand that switching engines be supplied with coke or other smokeless fuel. This would certainly help to mitigate the smoke nuisance.

With the smoke from factories and the railroads reduced to a minimum, the irreducible remainder, and the apparently incurable smoke from kitchen ranges and open fireplaces, would make a total so far below what most of our cities now endure that city life would be made notably cleaner and sweeter.

Recent Progress in Spectroscopic Methods—I*

Past Achievements and Future Prospects

By Prof. A. A. Michelson

AN observer who for the first time views the light of the sun through a prism cannot fail to express his wonder and delight at the gorgeous display of colors into which the white light is separated; and if the observation is made under the same conditions as in the celebrated experiment of Newton, 1666, there is, in truth, nothing else which he could observe. You will remember that he allowed a beam of sunlight to stream through a round opening in a shutter of his window, falling on a glass prism, which bent the sunrays by different amounts depending on their color, thus spreading out the white round sunlit spot on the opposite wall into a colored band—the spectrum—which he rather arbitrarily divided into seven colors—red, orange, yellow, green, blue, indigo, and violet. (If the division were made to-day I doubt if indigo would be included.) There is, in fact, no definite demarcation between these, and they shade insensibly into each other, and if the solar spectrum were always produced under these conditions we should say it was continuous; indeed, if it were not the sun, but an argand burner or an incandescent lamp, which served as source, it would really be so.

But even if the source consisted of isolated (but sufficiently numerous) separate colors, the fact would be disguised by the overlapping of the successive images. In other words, the spectrum is not pure. In order to prevent this overlapping, two important modifications must be made in Newton's arrangement.† First, the light must be allowed to pass through a very *narrow* aperture, and, secondly, a sharp *image* of this aperture must be formed by a lens or mirror.

The first improvement was introduced by Wollaston in 1802, who writes: "If a beam of daylight be admitted into a dark room by a *crevice* one-twentieth of an inch broad, and received by the eye at a distance of 10 or 12 feet through a prism of flint glass held near the eye, the beam is seen to be separated into the four colors only—red, yellowish-green, blue, and violet. . . . The *line* that bounds the red side of the spectrum is somewhat confused. . . . The *line* between the red and green . . . is perfectly distinct; so also are the two limits of the violet. There are other distinct lines (in the green and blue . . .)."

The second improvement was effected by Fraunhofer, 1814, and by observing the light which fell from such a narrow aperture upon a prism by means of a *telescope* he discovered upward of 750 *dark* lines in the solar spectrum, and mapped their position and general character.

In recognition of the enormous importance of this discovery, these lines are always known as the Fraunhofer lines.

A minor inconvenience in Fraunhofer's arrangement lay in the fact that the slit source had to be at a considerable distance from the telescope; and this was obviated in the apparatus of Bunsen and Kirchhoff, 1860, which is essentially the same as the modern spectroscope of to-day, consisting of a slit and collimator, prism, and observing (or photographic) telescope.

On this beautifully simple device rests practically the whole science of spectroscopy, with all its wonderful applications and all the astonishing revelations of the structure and motions of the sidereal universe and of the constitution of the atoms of matter of which it consists—nay, even of the electrons of which these atoms are built!

Without the telescope it is evident that the science of spectroscopy would be as limited in its field as was the science of astronomy without the telescope. It is interesting, indeed, to compare the progress of the two sciences as dependent on the successive improvements in the two instruments.

Without the telescope nothing could be discovered concerning the heavenly bodies (with the exception of a few of the more evident features of the sun, the moon, and the comets) except the brightness and places of the stars and the motion of the planets, and even these could, at best, be very roughly determined (say, to within one part in five thousand, or something over a half-minute of arc). Without the telescope spectroscopy would also have been limited to observations of general differences in character of radiations and absorptions, and a rough determination of the position of the spectral lines, with a probable error of this same order of magnitude.

In fact, the *resolving power* of the eye is measured by the number of light waves in its diameter, about 5,000, and if a double star (or a double spectral line) presents a smaller angle than 1/5,000 it is not "resolved." The resolving power of a telescope with a 1-inch objective would be about 100,000, so that details of the solar and lunar surfaces, and of planets, nebulæ, and of double stars and star groups can be distinguished the angular distance of which is of the order of 1/100,000. The disks of the planets, the rings of Saturn, the moons of Jupiter, and some star groups and clusters, begin to be distinguishable. Our largest telescopes have a resolving power as high as 2,000,000, corresponding to a limit of separation of one-tenth of a second.

But in order to realize the full benefit of the telescope when used with a prism, the latter must be so large that the light which falls upon it entirely fills the object glass. The efficiency of the prism then depends on its size and on its dispersive power.

In order to form an idea of the separating or resolving power in spectroscopic observations it will be convenient to consider the Fraunhofer line *D* of the solar spectrum or the brilliant yellow line corresponding to the radiation given out by a salted alcohol flame. This Fraunhofer recognized as a double line, and the length of the light-waves of the components are approximately 0.0005890 millimeter and 0.0005896 millimeter, respectively. The difference is, then, 6/5,893 of the whole, or about 1/1,000, requiring a prism of resolving power of 1,000 to separate them. If the prism were made of flint glass with a base of 25 millimeters it would just suffice to show that the line was double.

Now we know of groups of spectral lines the components of which are much closer than those of sodium. For instance, the green radiation emitted by incandescent mercury vapor consists of at least six components, some of which are only a hundredth of this distance apart, and requiring, therefore, a resolving power of 100,000 to separate them. This means a glass prism of 100 inches, the construction of which would present formidable difficulties. These may be partially obviated by using twenty prisms of 5 inches each; but owing to optical imperfections of surfaces and of the glass, as well as the necessary loss of light by the twenty transmissions and forty reflections, such a high resolving power has not yet been realized.

The parallelism of the problems which are attacked in astronomy and in spectroscopy is illustrated in the following table. It is interesting to observe how intimately these are connected and how their solution depends on almost exactly the same kind of improvement in the observing instruments, particularly on their *resolving power;* so that not only are the older problems facilitated and their solution correspondingly accurate, but new problems, before thought to be utterly beyond reach, are now the subject of daily investigation.

Astronomical.	*Spectroscopic.*
(1) Discovery of new stars, nebulæ, and comets.	Discovery of new elements.
(2) Star positions.	Wave-length of spectral lines.
(3) Double stars and star clusters.	Double lines, groups, and bands.
(4) Shape and size of planets and nebulæ.	Distribution of light in spectral "lines."
(?) Star disks.	
(5) Star motions (normal to line of sight).	Star motions (parallel with line of sight).
Resolution of doubles.	Resolution of doubles.
Solar vortices.	Solar vortices.
Protuberances, etc.	Protuberances, etc.
(6)	Changes of character and position of lines with temperature, pressure, and magnetic field.
	(7) Spectroheliograph.

(Combination of telescope and spectroscope.)

We must especially note that the newer problems require an enormous resolving power. In the telescope this has been accomplished partly by the construction of giant refractors and partly by enormous reflectors; and, curiously enough, the same double path is open to spectroscopy; for we may employ the analogous dispersive power of refracting media or the diffractive power of reflecting media. The increasing cost and difficulty of producing large transparent and homogeneous blocks of glass have tended to limit the size and efficiency of lenses and of prisms, and these have been more or less successfully replaced, the former by mirrors and the latter by *diffraction gratings.*

These are made by ruling very fine lines very close together on a glass or a metal surface. The effect on the incident light is to alter its direction by an amount which varies with the wave-length—that is, with the color; and a spectrum is produced which may be observed to best advantage by precisely the same form of spectrometer, with a substitution of a grating for the prism.

The dispersion of a diffraction grating depends upon the closeness of the rulings; but the resolving power is measured by the total number of lines. It is important, therefore, to make this number as large as possible.

The first gratings made by Fraunhofer, 1821, contained but a few thousand lines, and had a correspondingly low resolving power—quite sufficient, however, to separate the sodium doublet. A considerable improvement was effected by Nobert, whose gratings were used as test objects for microscopes; but these were

*Address by the retiring president of the American Association for the Advancement of Science.

†An anonymous writer in *Nature* points out that Prof. Michelson is in error here. We quote the passage in detail:

"Both these modifications were made by Newton himself, and with a clear understanding of their advantages. In 'Opticks,' Exper. 11, we read: 'In the sun's light let into my darkened chamber through a small round hole in my window—shut, at about 10 or 12 feet from the window, I placed a lens, by which the image of the hole might be distinctly cast upon a sheet of white paper, placed at the distance of six, eight, ten, or twelve feet from the lens. . . . For in this case the circular images of the hole which comprise that image . . . were terminated most distinctly without any penumbra, and therefore extended into one another the least that they could, and by consequence the mixture of the heterogeneous rays was now the least of all.'

"And further on:

"'Yet, instead of the circular hole *F*, 'tis better to substitute an oblong hole shaped like a long parallelogram with its length parallel to the prism *ABC*. For if this hole be an inch or two long, and but a tenth or twentieth part of an inch broad or narrower, the light of the image *pt* will be as simple as before or simpler [i. e., as compared with a correspondingly narrow circular hole], and the image will become much broader, and therefore more fit to have experiments tried in its light than before.'

"Again, it was not Bunsen and Kirchhoff who first introduced the collimator into the spectroscope. Swan employed it in 1847, and fully described its use in Edin. Trans., vol. xvi., p. 375, 1849. See also Edin. Trans., vol. xxi., p. 411, 1857; Pogg. Ann., C, p. 306, 1857.

"These are very minor matters as compared with what Prof. Michelson has to tell of his own achievements and experiences, but it seems desirable that they should be set right."

still very imperfect as spectroscopic instruments, and it was not until Rutherford, of New York, 1879, constructed a ruling engine with a fairly accurate screw that gratings were furnished which compared favorably with the best prisms in existence.

With 30,000 lines (covering more than 40 millimeters) the theoretical resolving power would be 30,000; practically about 15,000—sufficient to separate doublets the components of which were only one-fifteenth as far apart as those of the sodium doublet.

An immense improvement was effected by Rowland, 1881, whose gratings have been practically the only ones in service for the last thirty years. Some of them have a ruled surface of 150 millimeters × 60 millimeters, with about 100,000 lines, and can separate doublets the distance of which is only 1/100 of that of the sodium doublet in the spectrum of the first order. In the fourth order it should resolve lines the distance of which is only one-fourth as great.

Practically, however, it is doubtful if the actual resolving power is more than 100,000, the difference between the theoretical and the actual performance being due to the defect in uniformity in the spacing of the grating furrows.[1]

The splendid results obtained by Rowland enabled him to produce the magnificent atlas and tables of wave-lengths of the solar spectrum which are incomparably superior in accuracy and wealth of detail to any previous work; so that until the last decade this work has been the universally accepted standard. With these powerful aids it was possible not only to map the positions of the spectral lines with marvelous accuracy, but many lines before supposed simple were shown to be doublets or groups; and a systematic record is given of the characteristics of the individual lines, for example, whether they are intense or faint, nebulous or sharp, narrow or broad, symmetrical or unsymmetrical, reversed, etc.—characteristics which we recognize to-day as of the highest importance, as giving indications of the structure and motions of the atoms whose vibrations produce these radiations.

One of the most difficult and delicate problems of modern astronomy is the measurement of the displacement of spectral lines in consequence of the apparent change of wave-length due to "radial velocity" or motion in line of sight. This is known as the Doppler effect, and had been well established for sound waves (a locomotive whistle appears of higher pitch when approaching and lower when receding); but it was only confirmed for light by Huggins and by Vogel in 1871, by the observation of displacements of the solar and stellar spectral lines.

It may be worth while to indicate the accuracy necessary in such measurements. The velocity of rotation of the sun's equator is approximately 2 kilometers per second, while the velocity of light is 300,000 kilometers per second. According to Doppler's principle, the corresponding change in wave-length should be 1 : 150,000—a quantity too small to be "resolved" by any prism or grating then in existence. But by a sufficient number of careful micrometer measurements of the position of the middle of a given spectral line, the mean values of two such sets of measurements would show the required shift. It is clear, however, that if such radial velocities are to be determined with any considerable degree of accuracy, nothing short of the highest resolving power of the most powerful gratings should be employed.

Another extremely important application of spectroscopy to solar physics is that which, in the hands of Hale and Deslandres, has given us such an enormous extension of our knowledge of the tremendous activities of our central luminary.

The spectroheliograph, devised by Hale in 1889, consists of a grating spectroscope provided with two movable slits, the first in its usual position in the focus of the collimator, and the second just inside the focus of the photographic lens. A uniform motion is given to the two slits so that the former passes across the image of the solar disk, while the other exposes continually fresh portions of the photographic plate.

If the spectroscope is so adjusted that light of the wave-length of a particular bright line in a solar prominence (say, one of the hydrogen or the calcium lines) passes through the instrument, then a photograph of the prominences, or sun-spots, or faculæ, etc., appears on the plate. But the character of this photograph depends on the portion of the bright spectral "line" which is effective, and as the entire range of light in such a line may be only a thirtieth part of the distance between the sodium lines, it would require a resolving power of at least 100,000 to sift out the efficient radiations so that they do not overlap.

As another illustration of importance of high resolving power in attacking new problems, let us consider the beautiful results of the investigations of Zeemann on radiation in a magnetic field. The effect we know is a separation of an originally simple radiation into three or more, with components polarized at right angles to each other. This is one of the very few cases where it is possible actually to alter the vibrations of an atom (electron), and the fact that the effect is directly calculable, as was first shown by Lorentz, has given us a very important clue to the structure and motions of the atoms themselves.

The experiment is made by placing the source of radiation (any incandescent gas or vapor) between the poles of a powerful electromagnet and examining the light spectroscopically. Now this experiment had been tried long before by Faraday, but the spectroscopic appliances at his disposal were entirely inadequate for the purpose.

Even in the original discovery of Zeemann only a broadening of the spectral line was observed, but no actual separation. In fact, the distance between components which had to be observed was of the order of a hundredth of the distance between the sodium lines, and in order to effect a clear separation, and still more to make precise measurements of its amount, requires a higher resolving power than was furnished by the most powerful gratings then in existence.

As a final illustration, let us consider the structure of the spectral "lines" themselves. Rowland's exquisite maps had shown many of these, which were then thought simple, to be double, triple, or multiple, and there are clear indications that even the simpler lines showed differences in width, in sharpness, and in symmetry. But the general problem of the distribution of light within spectral lines had scarcely been touched. Here, also, the total "width" of the line is of the order of 1/100 of the distance between the sodium lines, and it is evident that without more powerful appliances further progress in this direction was hopeless.

To be continued.

[1] This applies to all the Rowland gratings which have come under my notice, with the exception of one which I had the opportunity of testing at the Physical Laboratory, University, Göttingen. The resolving power of this grating was about 200,000.

The Resistance of the Air and Aviation

Eiffel's Memoir on Experimental Aerodynamics

By Dr. A. F. Zahm

THE famous builder of the Eiffel Tower, and past president of the Society of Civil Engineers of France, has of recent years dedicated, liberally and with distinguished success, his time, his resources and his abilities, to the advancement of the general science of experimental aerodynamics, and particularly those portions of it which seem most essential to the rational development of aviation. He has made two series of elaborate investigations. In the first, various models were allowed to fall in the free air from the Eiffel Tower, guided in their descent by a vertical cable. In the second series various models were exposed to an artificial wind generated in a laboratory designed expressly for that purpose. These latter experiments will be briefly reviewed in the present article.

Mr. Eiffel has given the results of his investigations promptly to the world either in memoirs or in periodicals, and always with an elegance of illustration, expression and method which may be regarded as a model of presentation in applied science and engineering. In 1907 appeared his "Recherches Experimentales sur la Résistance de l'Air Exécuté a la Tour Eiffel," a handsome quarto volume of some hundred pages, profusely illustrated with photographs and drawings, giving a full account of his first method of air resistance measurement, together with the data obtained and the conclusions derived from them. In 1910 followed "La Résistance de l'Air, Examen des Formules et des Experiences," a concisely written octavo volume of two hundred and fifty pages reviewing the experiments of students of aerodynamics previous to that date, and announcing the first results obtained in his then newly constructed laboratory. Shortly after this, and bearing the same date, 1910, appeared the splendid memoir which forms the subject of the present review, "La Résistance de l'Air et l'Aviation," a quarto volume comprising one hundred and thirty pages of text, together with an equal number of pages devoted to diagrams and data. This last work represents Eiffel's maturest experience and conclusions in aerodynamical research. It forms, indeed, a worthy monument to his liberality and scientific spirit, as also to the skill of himself and his associates. Let us add further that it furnishes a fine example of how a competent man of means can, without concerning himself about dividends or financial profits, materially promote the progress of science and industry, thereby meriting the permanent esteem and gratitude of his country and of humanity. Not all men of wealth, it is true, have the requisite training to prosecute science directly and of their unaided initiative, but by co-operating with an unhampered staff of trained and experienced investigators the most important and fruitful work can be accomplished.

Mr. Eiffel, having abandoned open air experiments, and wishing to place his models in a wind of uniform speed and direction, built the laboratory and wind course shown in Fig. 1. and Fig. 2. The air starting from rest in the room *k* passed through a funnel and "honeycomb" to the measuring room where the model to be tested was placed, thence through a second funnel to a suction fan *g*, driven by an electric motor, thence through a return channel to the first room. The current emerging from the honey-comb was 1.5 meter in diameter and of a uniform velocity whose magnitude was accurately computable from the pressure difference in the first and second rooms mentioned. The wind speed could be varied from five to twenty meters per second. The wind force on the model was found directly by balancing it against weights placed on the wind balance supporting the model as shown; also by measuring the point-pressure at each part of the model's surface by the manometric method introduced by earlier investigators, the manometers having inclined alcohol tubes graduated to one-fourth millimeter of water. The building which comprised these rooms and instruments measured 20 by 12 meters in plan, by 9 meters high.

Two general classes of wind objects were studied; those of exact geometrical form, and those of unmathematical figure. The exact geometrical forms comprised planes, circularly arched plates, cylinders, cones, etc.; the other shapes were patterned after well known aeroplane wings. The data and results of the experiments are presented graphically in the text, and numerically in the Appendix of Eiffel's elegant work.

In these, as in his previous air resistance measurements made on falling bodies, Eiffel found, as had most of his predecessors, that the resistance of all wind objects, at speeds below fifty meters per second, varies directly as the square of the relative velocity of air and model. This relation is true enough of blunt bodies, but not so true of planes moving nearly edgewise, and of easy shapes, in which the surface friction is a considerable factor; for the friction does not vary as the square of the velocity, but according to a lower power, as proved by the present writer nearly one decade ago.

The neglect of surface friction also led Mr. Eiffel

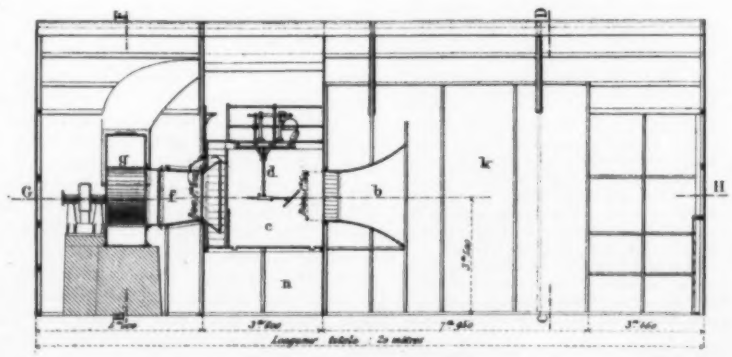


Fig. 1.—Wind Course for Testing Aeroplanes.

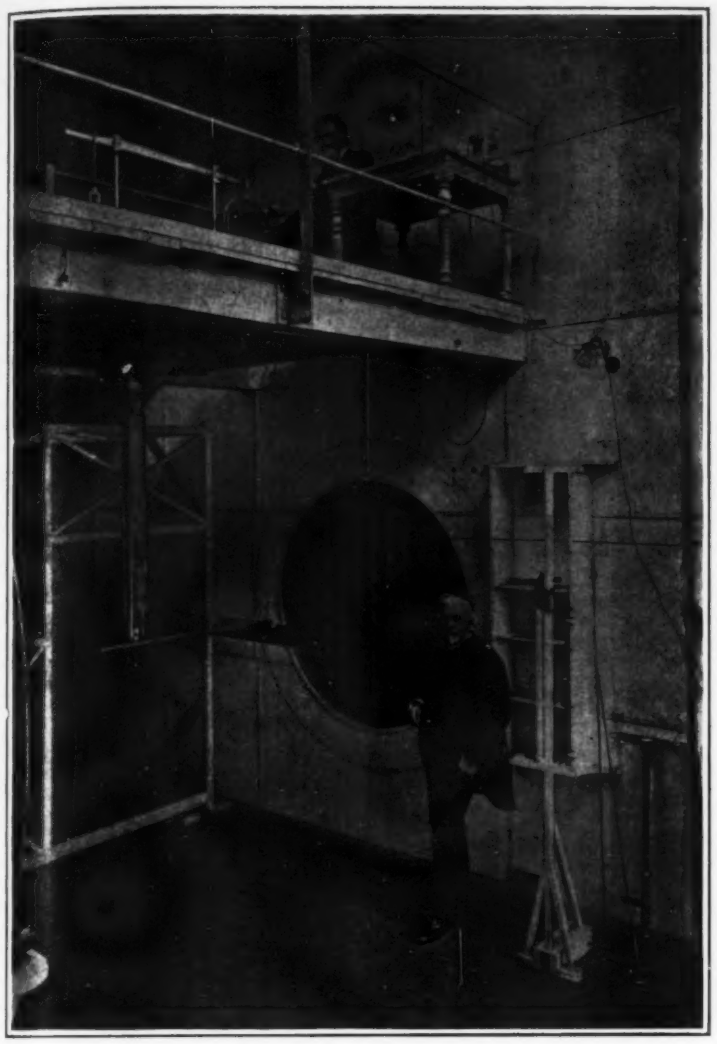


Fig. 2.—The Famous French Engineer, G. Eiffel, in His Aerodynamic Laboratory.

to state that the whole wind force on a model, as measured directly by his aerodynamic balance, equals the summation of the unit pressures at all parts of the model, as shown by the manometer. This statement is true of a plane set normal to the wind, but wholly untrue of one set edgewise or at a very small angle. It is untrue of all models in which the friction is a considerable element of the entire resistance, as of good hull forms, double wedges and easy shapes generally.

Assuming the usual formula for the resistance of blunt bodies, $R = K S V^2$, Eiffel found that the constant of figure K varies with the ratio of length to breadth of any sustaining surface of given area S, being greater as this ratio increases; and, for inclined surfaces, being greater when the model advances long side foremost. These general truths have been long known, but not in the exact quantitative manner disclosed by Eiffel's researches. The magnitude of the resultant pressure on inclined plane rectangular surfaces was for all angles of inclination likely to be used in aeroplane wings, found to increase directly as the angle of incidence, as proved by others. The ratio of the whole wind pressure against an inclined rectangle to the pressure at ninety degrees was found to be closely expressed by the formula $(0.032 + 0.005n)i$ for angles i up to ten or twelve degrees, and for elongations n from one to nine; so closely indeed that Eiffel favored abandoning all previous formulæ proposed by his predecessors for this important relation. Square and nearly square planes were found to have greater resistance at angles of twenty-five to forty-five degrees than at normal incidence. The values of the above ratio found for several plane surfaces are well exhibited in Fig. 3.

The center of pressure of flat rectangular surfaces at various angles of flight was found generally to move from the center of figure toward the forward edge as the inclination decreased from ninety degrees to about the ordinary angles of flight. For angles of incidence neighboring five degrees the center of pressure was found nearly midway between the center of figure and the leading edge of the plane rectangle, as shown in Fig. 4.

Similar experiments were made on circularly arched rectangular surfaces of various camber, or amount of curvature. The wind force for three such surfaces and for a plane, each measuring 90 by 15 centimeters, is delineated in Fig. 5. The radius vector drawn to any point of a curve represents the wind force in magnitude and direction, while the angle of incidence corresponding to that force is marked on the curve near the point. The lift and drift of the wind force, being merely its rectangular components, are clearly disclosed by the diagram, and show by their ratio which surface is the most efficient carrier at any given angle. Thus, at ordinary angles of flight the most effective of the four surfaces represented appears to be the one whose camber is 1/13.5; for this gives a comparatively large lift with a small horizontal resistance.

Space will not permit the presentation of Eiffel's diagrams showing the point pressure distribution on the above figures, nor his most valuable and interesting studies of the wind force on many wing forms, and on parallel surfaces, both tandem and superposed. These are recommended to the reader's careful study, as they are important and unique. Indeed, one of Eiffel's greatest services to aerodynamics is his study of the point pressure of the air on models not only at one portion of their surface but at every portion where it is unknown or can not be inferred from symmetry, thus furnishing a complete map of the pressure distribution. For practical availability and thoroughness Eiffel's memoir is one of the finest that has yet appeared in aerodynamics.

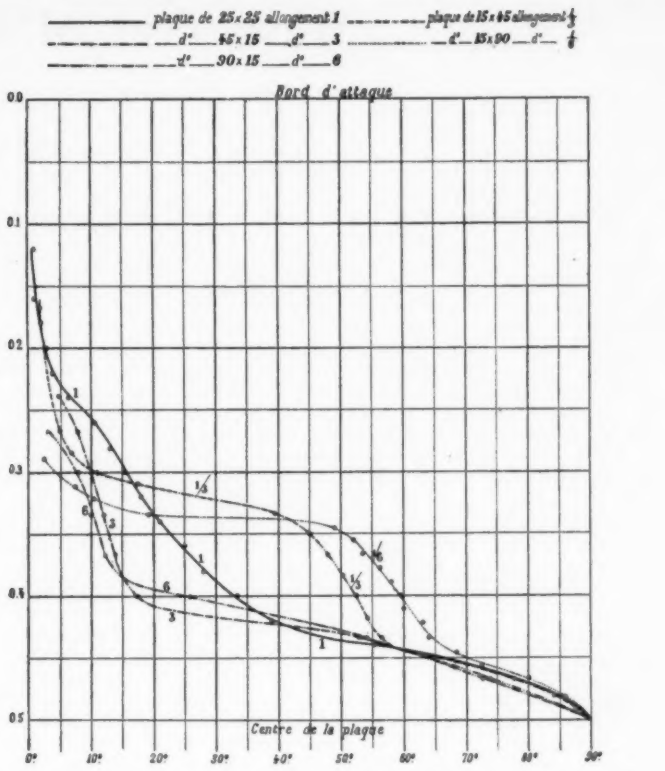

plaque de 25x25 allongement 1
plaque de 15x45 allongement 1/3
d° 45x15 d° 3
d° 15x90 d° 1/6
d° 90x15 d° 6
Bord d'attaque
Centre de la plaque

Fig. 4.—Position of Center of Pressure for Different Angles of Incidence.

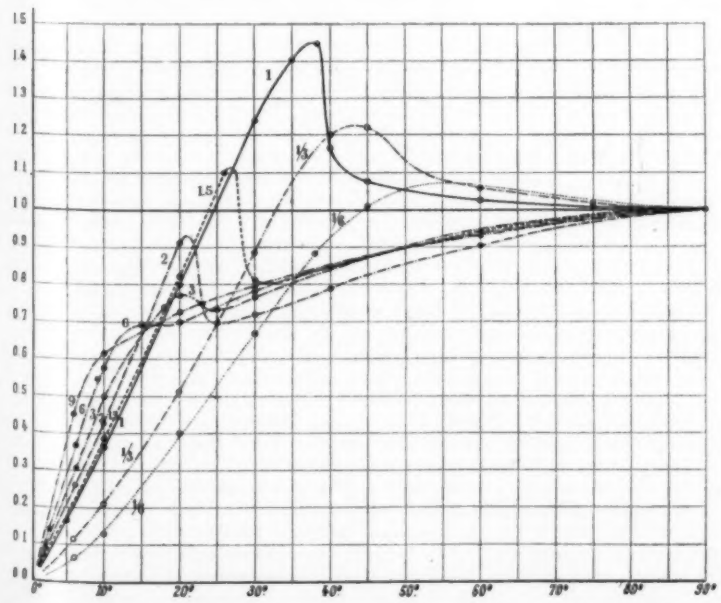


Fig. 3.—Ratio of Whole Wind Pressure at Different Angles of Incidence to that at Ninety Degrees.

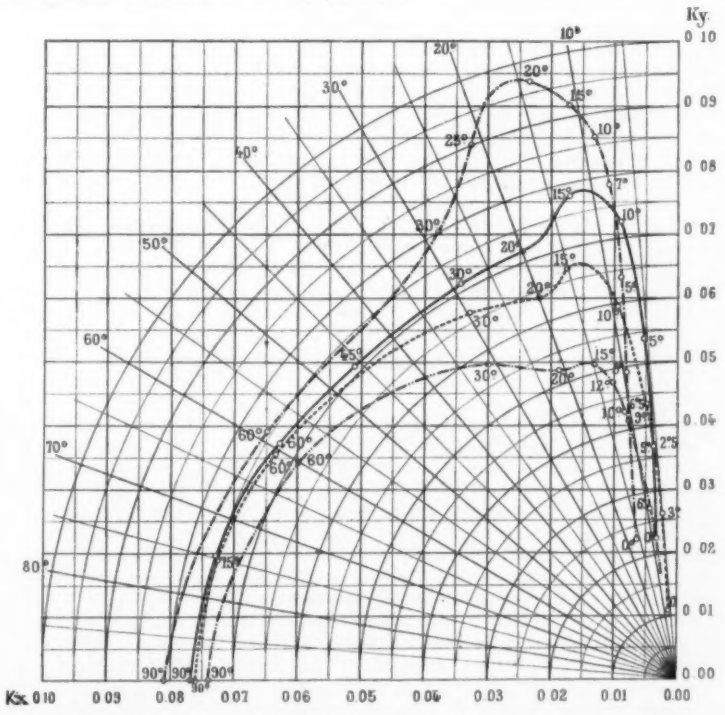


Fig. 5.—Polar Diagram of Wind Pressure on Plane and Curved Surfaces

The Art of Color Photography*

Its Present State and the Prospects for the Future

By Dr. J. A. Stärcke

"THE INTERFERENCE PROCESS."

In 1891 Lippmann brought out his "Interference" process, the most ingenious and original of all the methods of color photography, in that by it colors are produced without the help of coloring materials. This result is produced by placing a layer of quicksilver behind the plate in a specially contrived plate-holder and in contact with a very transparent emulsion. When exposed in the camera, the direct rays of light pass through the plate and film and are reflected back by the quicksilver, producing maxima and minima light-waves. On development, infinitesimal scales of metallic silver are formed in the film, which, when viewed by reflected light, show the natural colors of the object. While one is astonished at the simplicity of the means by which the colors are produced, the Lippmann process is so far the least practical, since it requires a lengthy exposure and its reproduction of mixed colors, like brown, is defective. Besides, the colors can only be seen to advantage when the plate is viewed at a certain angle, and best when coated with a varnish of Canada balsam or in a tray containing benzole.

THE FILTER PROCESSES.

As far as can now be determined, the idea of combining a three-color line filter with a sensitized photographic plate was originated by Ducos du Hauron, who took out a patent in France in 1868 on this method. Later the idea was taken up by others, among them Dr. Joly, of Dublin, Ireland, who in 1896 made a line filter with six lines to the millimeter. Soon finer and improved filters were produced, but their manufacture was so difficult and expensive that they were found impracticable. McDonough, of Chicago, attempted to make them on a large scale and formed a company for that purpose, but after spending nearly half a million dollars fruitlessly, the company was dissolved.

Within the last few years the technique of color-filter making has made extraordinary progress, and at the present moment filters are produced based on every possible theory, many of them being already on the market. There are to-day some twenty-four different filters for photographing colors, some of which, however, have not yet got beyond the stage of laboratory experiments, although patents have been applied for. There are already ten or more kinds of color plates or films on sale.

The father of the granular filter is not Lumière, but James McDonough of Chicago. (As a matter of fact Ducos du Hauron as long ago as 1869 expressed the possibility of a three-color filter of this kind.) Certainly the American covered a good deal of the ground taken by the Lumière brothers in their autochrome plate, for although they conquered the technical difficulties in a brilliant manner, a specification covering all granular filters had been filed by McDonough in his patent in 1892, which claims: "The preparation of filter plates by covering a glass plate with a sticky varnish or similar substances, upon which is spread a mixture of very fine, colored granules, which may consist of powdered glass, transparent coloring matter, gelatine, rosin or shellac, colored with aniline coloring materials." He mixed the colors in the proper proportions, forming a gray mass which he applied to the plate; over this layer he put a panchromatic emulsion and exposed his plate on the glass side. It will thus be seen that McDonough did not leave much for the Lumières apart from solving the technical problems and—taking in the shekels.

A REVIEW OF THE VARIOUS SYSTEMS.

A complete description of all that has been discovered, imagined or invented, relating to color filters, would easily fill a good fat volume; so we can merely mention a few of the more important points which will give some idea of how far the fundamental principles have been worked out and how the rolling pebble has become an avalanche.

McDonough's basic idea has probably been fully worked out: almost every possibility named by him for preparing color filters has been tried. In 1908 Bamber used gelatine, hardened with formalin and ground to powder. In the same year, Brasseur and others employed granules of celluloid, which was cooled by liquid air, that makes it extremely brittle and permits it to be ground to a fine powder. In 1908, also, Hermann used colored solutions of shellac in alcohol mixed with oil of turpentine and emulsionized with gum damar. This produces very minute globules, just as oil does when shaken up with water. The plate was first coated with a thin shellac varnish to which the granules were made to adhere by pressure. A similar plan was followed by Christiansen, in 1909, who made viscous solutions of dextrine, rosin or similar substances in emulsion with coloring matter, and the colored granules were mixed with benzine and flowed over the plates; after which a thin varnish of shellac or rubber was applied.

In several of these methods (among them the Autochrome) the plate requires to be rolled in order to flatten the granules and close the interstices which would allow white light to pass. A contingency of this rolling was that the glass plates were often broken; this difficulty has recently been remedied by using a very narrow roller, covering only a narrow strip of the plate at a time.

A unique application of colored powders is made in the "Vera" plate of Szczepanik and Holborn. In this plate the affinity some colors possess for certain substances is utilized. A gelatine powder in three colors is spread over a moist collodion plate. The basic coloring matter gradually penetrates the collodion and the decolored gelatine is washed away. The result is a mosaic of minute, not sharply defined, colored fields. By a later modification of the "Vera" plate the gelatine powder is used for two colors only, the third color being replaced by uncolored gelatine, and after preparing as above the third color is applied by placing the plate in a bath of dye.

Finally the idea occurred to Wolf-Capek and to Borrell & Pinoy, in 1907, to employ globular bacteria for preparing color filters; these bacteria are much smaller than the starch-grains of the Autochrome. Neither of these, however, can be said to have got beyond the experimental stage; for it is a question whether the extreme minuteness of the "ball" bacteria may not prove an obstacle to its practical employment for this object. Nevertheless it is a most original conception. The bacteria referred to is called *Staphylococcus pyogenes*, a suppuration microbe, the average size of which is from 1/5,000 to 1/500 of a millimeter; while the starch granules used on the Autochrome are about 1/80 to 1/60 of a millimeter. Cultures of these microbes are colored with aniline dyes, mixed in proper proportion and fixed on a glass plate. It is doubtful, however, whether it will be possible to eliminate the interstices and their ill-effects.

THE LINE FILTERS.

Many different methods have been invented for producing line filters, in which the peculiar properties of various substances, long known to the world, have been utilized in conjunction with other properties that have only recently been discovered. In the majority of the methods a preliminary screen, consisting of very fine black lines with intervening spaces double the thickness of the lines, is prepared by photographic means. This screen is used to prepare the regular three-color filter by exposing the sensitized gelatine film under the black-and-white screen and coloring the portion that was covered by the black lines only; the plate is then again coated, the screen moved the width of the black line and exposed for the second color, and so on.

Frequently use is made of the power of oil to repel water. For instance, two colors in oil are applied to the plate by crossing the lines, and the third color is put on by dipping in water-color which dyes the third and yet uncolored space but does not affect the oil-colors. In some methods the oil is employed merely to protect the portions that are not to be colored. The Dufay plate belongs to this class.

This brings us to another principle—"immunizing"—a term borrowed from modern literature on infectious diseases. Gelatine can be immunized or rendered non-receptive to a large number of coloring substances by an agent that hardens it and at the same time acts as a mordant for the first color. It is upon this principle that the new Krayne line-filter (1908) is based. The space between the first set of lines is covered with oil ink and the color applied by dipping; the plate is then placed in a solution of chloride of iron, which hardens the gelatine and fixes the color.

Quite different is the mode of procedure with the "Omnicolor" plate. The gelatine is first covered with a green waterproof varnish, on which the lines are drawn, cutting through to the gelatine. The plate is then dipped in an orange-red dye which penetrates the gelatine through the lines. A second coat of varnish is then applied and a second series of lines drawn at an angle with the first set and somewhat deeper; the plate is now immersed in a blue-violet bath which completes the filter.

In several of the processes use is made of the property of bichromatized gelatine to become impervious to water when exposed to light. Generally three coats are applied, each being exposed in turn and colored. Sometimes the unexposed gelatine, which remains soluble, is washed away before the color is put on. This was the way with the Warner-Powrie plate, invented in 1905 by Mr. J. H. Powrie, for which Miss F. Warner furnished the capital. The complete Warner-Powrie plate resembles Dufay's with lines about the same size.

In the "Thames" color-plate (Finlay, 1906) three coatings of gelatine are also employed—one for the green, one for the red, and the third for the blue interspaces. The peculiarity of the Thames plate is that the red and green spots do not closely join, so that a slight variation in register when making the filter is not so important. The Thames filter is somewhat coarse and the spaces larger than in the Dufay plate.

In fineness of grain, no plate, yet placed on the market, comes near that of the Autochrome. Each square millimeter of the Dufay has 170 colored elements (dividing the green stripes into squares); the Omnicolor has 320, and the Autochrome has from 7,000 to 8,000 starch granules. Even if account is taken of the fact that the granules on the Autochrome frequently lie in clusters of one color, it is still far ahead of its competitors. On the other hand some of the other filters allow more light to pass through: against 7.5 per cent passed by the Autochrome the Omnicolor passes 10, the Thames 12, and the Dufay 21 per cent of the light falling upon them.

The Wratten filter (1907) is peculiar in that only one coat of gelatine is used and only one exposure, and yet it gives the three colors. A very fine checker-work of alternate black, gray, and white squares is printed on the gelatine, which is then colored blue. After exposure the filter is washed, leaving a series of white, light blue and blue squares alternately. Then the filter is placed in a yellow bath which takes a good hold on the unexposed gelatine and on the gray squares just a little, changing the sequence to yellow, green and blue. Finally, the filter is placed in carmine dye which penetrates the squares still remaining soft, changing the colors to light red, green and blue. Though there are practical difficulties in the way of producing a very fine filter of this kind, a beginning has been made with a somewhat coarse plate.

By Faupel's method (1907) a chromated gelatine plate is exposed under a system of lines and colored in a blue dye which takes only on the unhardened gelatine; it is then placed in red dye which takes only on the hardened portion. A new coat of gelatine is now applied and another set of lines printed at right angles to the first series, dividing the blue stripes into hardened and unhardened squares. The plate is now placed in yellow dye, which acts only on the unhardened squares, changing their color to green.

BLOCK FILTERS.

In conclusion we must mention the filters of thread tissue and of the block-cutting type. The idea of this method seems to have originated with Dr. O. N. Witt in 1908. Thin sheets of collodion or celluloid, alternating in the three colors, are piled together and pressed into a block which is again shaved into thin sheets at right angles to the first layers. This gives a filter consisting of thin colored stripes of same thickness as the original sheets before pressing. The Krayne filter (1906) was at first made in this way. It was found, however, that the cutting machines, or microtomes, could not cut out fine enough to give the required number of lines to the millimeter, and in pressing the blocks the sheets were sometimes twisted so that the lines ran irregularly. To obviate this, celluloid sheets of a given thickness are rolled or pressed down as thin as necessary. The Krayne "mosaic" filter is made by again piling and pressing the sheets made by the microtome and cutting at right angles to the lines, so as to give small colored dots instead of lines.

In the same category we must count the method of Ramon-y-Cajal, principal of the weaving school in Madrid—one of the many doctors who have interested themselves in color photography. He employed colored fibers held together by a solution of celloidin and pressed into a block which was cut into sheets by a microtome as above. In order to have the interstices filled in black, he mixed nitrate of silver with the celloidin and developed the sheets in pyro.

Finally, the thread tissue filters show regular progress. Joly (1895) took colored silk threads or other fibers, laid them on a transparent support and varnished them. Later Bertons and Gambs (1896) used a fine tissue (the best is artificial silk); also Szczpanik

* The review here given is derived from the Dutch magazine *Lux* through a translation published in *Camera*.

and Fritz (1898). Artificially prepared thread has the advantage that its thickness, flexibility and refracting power can be regulated at will. By the latter method the finely woven tissues are blocked and cut as before, but at an angle of 45 degrees from the direction of the threads, in order to avoid too great length in any single thread. By cutting diagonally, theoretically small colored ovals would result, but in practice the tissue is placed in a liquid which swells the threads, pressing them together and closing the intervening spaces.

There remain to be mentioned the plates prepared with ceramic colors, such as the "Aurora," which are somewhat coarse; the Wood light-refraction method, in which the plate has to be viewed in the same position as the picture was taken in; and last of all the chimerical method of the Russian, Loundine, which, according to published statements, is neither a filter nor an interference system, and about which nothing is yet known with certainty.

We will now briefly inquire what color photography has at present to offer us and what further we may expect from it. We hope, in the first place, to get quicker plates that will make shorter exposures possible. But we need not worry about that when we consider that where formerly ordinary plates required many minutes' exposure, we now have them effective at an infinitesimal fraction of a second; may we not hope, therefore, that the panchromatic emulsions behind their color filters and compensation filters will, before long, be made capable of instantaneous exposures? Even now snap-shots can be made with especially good light—full sun—of mountains or the sea, with an opening of *f* 2 to *f* 4.

MANIFOLDING PROCESSES.

Another desideratum is the possibility of manifolding color photographs by printing on paper or on transparent plates. Of course it is possible to copy an Autochrome picture on another Autochrome plate, but in doing this a number of difficulties present themselves, causing faults in the reproduction of the colors, and in spite of the first enthusiastic reports of the copying of Autochromes on Autochromes in the plateholder, with the camera pointed toward a patch of gray sky and using a yellow compensation filter, or in the Lumière apparatus consisting of a long box in front of which magnesium ribbon is burnt, the fact remains that it is impossible to obtain a correct reproduction of the original colors in this way. This opinion has been confirmed recently from many sides for the following reasons: Suppose, for instance, that a dark red spot in an Autochrome original consists of 300 red granules mixed with 600 black granules; then if in printing on another plate the colored spots of one do not come exactly under similar spots on the other, of the 300 red granules scarcely 100 rays will fall on red granules in the copy plate, the other 200 red rays falling on green and blue granules and few or none pass through; so we will obtain in the copy a red consisting of 100 red granules mixed with 900 black granules, giving an entirely different tone from the original, and an enormous difference from the color of the natural object. Generally better results are obtained by copying color-plates by transmitted light, as only in this way can the necessary homogeneity of the colors be obtained.

There are three other methods of reproducing colored photographs from the original. The first consists in printing a separate film for each color and fastening these together over one another. For this several chromatic processes can be employed; but the method is very troublesome.

The second plan consists in printing on so-called "bleaching-out" paper, on which a mixture of three aniline colors with a sensitive emulsion is coated. When this is printed under the original plate only those colors which receive light through the same color in the original hold fast, the rest being washed or bleached out.

In spite of the optimistic reports about the new Utocolor paper, no way has yet been discovered for fixing the colors after they are printed. The aniline dyes retain their property of bleaching out, and the color print will entirely disappear in the light of day, so that it must always be kept in the dark.

The third method consists in printing on the so-called secret silver subchloride. The prints show rather flabby colors and are even less amenable to fixing than the Utocolor. While fresh they turn white in daylight; later they become black.

Nevertheless we turn hopefully to the future and venture the prediction that all the difficulties we have mentioned will be fully overcome—that our expectations will even be surpassed, and that new discoveries will be made, and new methods invented which at present are quite beyond our comprehension.

Shall Contagious Diseases Be Abolished?

What Modern Methods of Sanitation Should Do for Us

UNDER this heading the *Journal-Lancet* is publishing a series of articles written by Dr. H. W. Hill, with the purpose of spreading among the general public a clear and intelligent understanding of the circumstances that determine the spread of contagious diseases, and of the proper methods of combating them. The point urged and insisted upon with much emphasis is that all or nearly all infectious diseases are disseminated almost exclusively by the direct transmission of comparatively recent bodily discharges from an infected person to the mouth or nose of some other person. On the other hand, disease germs cannot as a rule exist for any great length of time outside the human body, so that garbage, offal and other matter, however offensive to the senses, does not in itself represent a severe menace to the population, except in so far as it may serve as the breeding and feeding ground for flies that carry the disease germs to food consumed by us.

Hence the center of our attention in fighting disease should be directed, not so much toward the maintenance of order and cleanliness—this alone is quite insufficient—as toward the prevention of the spread of germs from diseased persons.

Speaking of the economic aspect of the problem, Dr. Hill remarks: "From what has been said it must be evident that the *sine qua non* of all infectious diseases are their respective agents, and that, since the chief sources (infective persons) of these are known, the most logical efforts are those which concentrate on the prevention of the dissemination of these agents from these sources.

This is correct, not only in theory, but in practice, and presents an infinitely simpler administrative problem than that presented by the older hypotheses—not only in the minor infectious diseases, where these principles have been practically accepted by all, but even in tuberculosis itself.

Thus, if "general environment" be the great factor in tuberculosis, the two million people of Minnesota must have each his or her own individual environment brought up to and kept at some standard-level designed to maintain each individual in his or her own alleged "highest state of health."

If, however, the infectiveness of the disease be the great factor, only three thousand people (the actively infective cases) need this supervision, in Minnesota, and they need it, not for the improvement of their "general environment," but *merely to prevent them from infecting others*. This problem, even numerically, is but one seven-hundredth the magnitude of the other. Consider the utterly impracticable expense and difficulty of the State attempting to insure only the four chief factors—good food, proper temperatures, temperance, and repose—to two million people (to say nothing of the other "factors of safety" called for by those who lay chief emphasis on control of environment, i. e., abolition of foul air, smoke, dust, damp cellars, bad smells, dirty back yards, etc.), and contrast with this the expense of State supervision of three thousand people ***merely to the extent of confining their infective discharges to themselves.***

Dr. Hill sums up the principal points of his second paper as follows:

THE PRINCIPLE OF THE NEW PUBLIC HEALTH.

a. *Sources of Infectious Diseases.*

1. Infectious diseases are infectious because they are due to the growth in the body of minute animal or vegetable forms (germs), the transmissibility of these germs from body to body being the sole explanation why these diseases are "catching."

2. Wherever in the body the germs develop, they leave it chiefly in the discharges, or by routes of the discharges, of the nose and throat, bladder, or bowel, i. e., from the main orifices of the body.

3. The discharges infect another person practically only when that person takes the discharges, in some form, into the mouth or nose, except in trachoma and the venereal diseases.

4. Outside the body disease germs do not multiply in nature, except perhaps rarely, and very temporarily in milk, water, or similar fluids. In general, even typhoid bacilli disappear from water supplies within two weeks, without evident multiplication. If introduced into milk, most infectious-disease germs die out as the milk becomes acid, generally in a day or two. Infectious-disease germs are rarely found in garbage, and they quickly die out if deliberately added. Practical modern public health recognizes therefore that the bulk of most of the infectious diseases are derived directly, or almost directly, from infected persons, not much from infected things, except water, milk, food, and flies. The danger from the general environment of an infected person is therefore small. The *things* in his neighborhood need little consideration, except those very immediately about him and directly infected by his discharges, such as bedclothes, personal clothes, towels, eating utensils, and other material objects that may receive, and retain for a time, fresh moist discharges. If attention be efficiently directed to infected persons and their discharges, the general surroundings may be safely ignored, except in the rarest instances.

b. *Routes of Infectious Diseases.*

5. The routes by which the discharges of the sick person pass to the well person are exactly those by which the same discharges pass from the well person to the person in ordinary life; for nose and mouth discharges the route is through direct contact, the sputum, mouth-spray, and the hands; for bowel and bladder discharges, the hands chiefly, and for all discharges through things infected by them directly or through the hands, which then go to the mouth or touch things which go to the mouth; as food, water, milk, eating utensils, towels, pipes, etc. Flies also furnish an effective route. Water supplies are peculiar, because bowel and bladder discharges *en masse*, in the form of sewage, often enter them directly, at times being deliberately poured into them from city sewers.

6. The relative importance of these various routes in the carriage of infection varies much. The amount and freshness of the discharges, the number and virulence of the germs they contain, the size and frequency of the dose, and the number of susceptible persons who are dosed, must always be considered. Almost all the ordinary infectious disease germs die out quickly on exposure to direct sunlight and fairly rapidly in diffuse sunlight. When mucus, feces, and urine are thoroughly dried on furniture, door-knobs, etc., they are not readily removed again without moisture and friction, and when so removed the disease germs in them are likely to be dead or greatly reduced in recuperative power because of the drying. Hence, as a rule, *things* succeed in conveying infection only rather directly from the infector to the infectee, and practically only during the limited period when the germs are still fresh and moist.

c. *Control of Infectious Diseases.*

7. The new principles therefore place at the head of official public health activities, the search for and supervision of infected persons, and the control of the infected discharges, particularly their exclusion from food and drink. Prompt intelligent disinfection of all the excreta immediately after their discharge from the body, is the best weapon in the supervision of infected persons. Isolation of the infected person is the next best, and is more universally practicable, because immediate intelligent disinfection of discharges can rarely be secured outside of the very best hospitals for contagious disease. The search for and supervision of mild, early, convalescing, unrecognized, and concealed cases and carriers, as well as of frank cases, is necessarily an essential item in the scheme.

8. The modern public health department requires experts, but not experts in municipal housekeeping, in street cleaning, garbage disposal, smoke prevention, etc. Its experts are the vital statistician, the epidemiologist, the laboratory man, and the sanitary engineer, the latter dealing chiefly with the broad questions of water supply and sewage disposal.

SUMMARY.

At present the State's recognized function is limited to the prevention of disease, and even so chiefly to the prevention of a *part* only of the *infectious* diseases. Modern public health principles recognize that in the discovery and supervision of the infected person and of the routes of extension from that person, the chief secrets of such prevention lie.

Artificial Tobacco Leaves.—According to *Papier Zeitung*, a German has invented a process for the manufacture of artificial tobacco leaves. The stems and ribs of tobacco leaves, which form a waste product in the manufacture of cigar and smoking tobacco, are separated into fibers in a hollander or edgemill, etc., after having previously been soaked in a solution of caustic soda or potash. They are ground and worked until a smeary mass is obtained. This is dipped by hand and conveyed to a paper machine to be turned into sheets. The latter consist wholly of tobacco, possessing all the properties of the natural leaves. By subjecting them to suitable impressions, they may be given the appearance of natural tobacco leaves.

Rules Governing the Competition for the $15,000 Flying Machine Prize Offered by Mr. Edwin Gould

1. A PRIZE of $15,000 has been offered by Mr. Edwin Gould for the most perfect and practicable heavier-than-air flying machine, designed and demonstrated in this country, and equipped with two or more complete power plants (separate motors and propellers), so connected that any power plant may be operated independently, or that they may be used together.

CONDITIONS OF ENTRY.

2. Competitors for the prize must file with the Contest Committee complete drawings and specifications of their machines, in which the arrangement of the engines and propellers is clearly shown, with the mechanism for throwing into or out of gear one or all of the engines and propellers. Such entry should be addressed to the Contest Committee of the GOULD-SCIENTIFIC AMERICAN Prize, 361 Broadway, New York city. Each contestant, in formally entering his machine, must specify its type (monoplane, biplane, helicopter, etc.), give its principal dimensions, the number and sizes of its motors and propellers, its horse-power fuel-carrying capacity, and the nature of its steering and controlling devices.

3. Entries must be received at the office of the SCIENTIFIC AMERICAN on or before June 1st, 1912. Contests will take place July 4th, 1912, and following days. At least two machines must be entered in the contest, or the prize will not be awarded.

CONTEST COMMITTEE.

4. The committee will consist of a representative of the SCIENTIFIC AMERICAN, a representative of the Aero Club of America, and the representative of some technical institute. This committee shall pass upon the practicability and efficiency of all the machines entered in competition, and they shall also act as judges in determining which machine has made the best flights and complied with the tests upon which the winning of the prize is conditional. The decision of this committee shall be final.

CONDITIONS OF THE TEST.

5. Before making a flight each contestant or his agent must prove to the satisfaction of the Contest Committee that he is able to drive each engine and propeller independently of the other or others, and that he is able to couple up all engines and propellers and drive them in unison. No machine will be allowed to compete unless it can fulfill these requirements to the satisfaction of the Contest Committee. The prize shall not be awarded unless the competitor can demonstrate that he is able to drive his machine in a continuous flight, over a designated course; and for a period of at least one hour he must run with one of his power plants disconnected; also he must drive his engines during said flight alternately and together. Recording tachometers attached to the motors can probably be used to prove such performance.

In the judging of the performances of the various machines, the questions of stability, ease of control and safety will also be taken into consideration by the judges. The machine best fulfilling these conditions shall be awarded the prize.

6. All heavier-than-air machines of any type whatever—aeroplanes, helicopters, ornithopters, etc.—shall be entitled to compete for the prize, but all machines carrying a balloon or gas-containing envelope for purposes of support are excluded from the competition.

7. The flights will be made under reasonable conditions of weather. The judges will, at their discretion, order the flights to begin at any time they may see fit, provided they consider the weather conditions sufficiently favorable.

8. No entry fee will be charged, but the contestant must pay for the transportation of his machine to and from the field of trial.

9. The place of holding the trial shall be determined by the Contest Committee, and the location of such place of trial shall be announced on or about June 1st, 1912.

10. Mr. Edwin Gould, Munn & Co., Inc., publishers of the SCIENTIFIC AMERICAN, and the judges who will be selected to pass upon machines, are not to be held responsible for any accident which may occur in storing or demonstrating the machines on the testing ground.

The History of the "Water-bath."—In Theophrastus work "De odoribus" mention is made of the water-bath, for the first time, in connection with the preparation of aromatic oils. Some of these, according to the work, are prepared by using made-rate heat. The passage in question, translated from Greek, is as follows: The boiling must be done in receptacles, placed in boiling water, and not by the action of direct heat. This is most necessary as only moderate heat should be used. If exposed to the open fire, it would result in a great loss of aromatic substances, besides the oil would take on a smell of burning.—*Archiv., Gesch., Nat., and Technik.*

Science Notes.

Does a Snail See?—Prof. Emile Yung of Geneva has made over 2,000 observations on 176 snails and concludes that they were quite indifferent to all sorts of light-stimuli, that they have no preference for lighted or shaded areas, and that they do not see obstacles in front of them, so that their eyes have no visible significance at all.—*Knowledge.*

The Most Expensive Book in the World.—The most expensive book is not the Gutenberg Bible, which was sold in a New York auction room some time ago for $50,000, but the "Missale Speciale" (a church service book for the diocese of Constance) in the possession of Mr. L. Rosenthal of Munich. It is the only copy known, is printed in red and black on vellum, and is supposed to have been produced by Fust and Schoeffer at Mayence, about 1400. It originally contained 102 leaves, but 14 are missing. The price asked is $75,000, or about $852 a leaf.—*Caxton Magazine.*

Glycerine as a Food Stuff.—The question has been raised in France whether glycerine can be regarded as a food material, inasmuch as it enters into the composition of certain candy and similar materials for consumption. The final decision reached is that glycerine has little or no food value, and that, moreover, its habitual ingestion may not be without evil effects. Prof. Pouchet, who has drawn up the report for the government, accordingly recommends that the use of glycerine as an alimentary product be not sanctioned.

Hygienic Advice to Smokers.—A writer in *Le Temps* gives the following advice to devotees of Lady Nicotine. Avoid moist tobaccos, which allow nicotine to pass off undecomposed with the water vapor. Do not smoke on an empty stomach nor shortly before a meal. Smoke cigars or cigarettes with a mouthpiece of amber, meerschaum, horn or cherry wood. As nicotine vaporizes at 250 deg. Cent., the portion which remains undecomposed in the glimmering tip tends to distill over toward the mouth end. For this reason it is well to reject the last quarter of a cigar or to use pipes with a long stem or reservoir. The cigarette, unless indulged in to excess, is, of all modes of smoking, the least harmful.

Tsumugi Cloth.—Tsumugi cloth is a Japanese cloth, largely manufactured at Naze, the capital of Amame Oshima Island in the southwestern part of Japan. Imported pongee silk is twisted into rather heavy strands of several threads and then woven into a coarse cloth, cotton thread being used for the warp. This cloth is then put for about 30 minutes into dying vats, the dye being obtained from a wood known as "tetsugi." It is then dried in the sun and put back into the vats, this process being repeated about ten times. The cloth is next buried in the ground for 7 or 8 days (some say 5 to 6 years, but this seems questionable), which fixes the dye, so that it does not run, and at the same time rots the cotton warp. The silk strands are then torn from the rotted warp and rewoven. The undyed spots left where the cotton warp crossed the silk, form the basis for the different designs of the cloth. Its durability and somber colors appeal to the Japanese, and it is in great demand. About 100,000 tans of this cloth are woven annually in the vicinity of Naze and sell for about $7.50 per tan. (A tan varies from 27 to 32 feet, averaging about 29 feet, and is from 14 to 16 inches wide.) The best Tsumugi cloth may be worth as much as $50 per tan. The cloth is used chiefly for making kimonos and lately has become popular for fancy vests. The manufacture of the cloth is gradually passing from the homes to small factories.—*Consular Report.*

Vagaries of the English Language.—Prof. A. F. Chamberlain, of Clarke University, writing in the *Popular Science Monthly*, draws attention to some remarkable examples of hybrid words in the English language. Probably the most extraordinary instance quoted is the very commonplace word "remacadamizing." It is pointed out that this word resolves itself into the following components: (1) re-, a Latin prefix, signifying "a repetition, or doing over again"; (2) mac, a Gaelic word for "son," in common use as a prefix for genealogical purposes; (3) Adam, the representative in a number of European languages (including Gaelic and English) of the Hebrew name of the first man, according to the Mosaic account of the creation as given in the first book of the Bible; (4) -iz (or -ize), the modern English representative, through French -iser, of the Greek verbal terminal *ίζειν*; (5) -ing, the English suffix of the participle present, verbal noun, etc. The word remacadamizing thus represents five languages: Latin, Gaelic, Hebrew, Greek and English. The "root" (macadam) of this word exhibits also in another way the vitality of our English speech and its ability to draft new words into its vocabulary, whenever the need arises. The term macadam is really the family name of the man, John Macadam, who, in 1819, devised the well-known method of paving roads with small broken stones, etc. Celtic and Semitic had already combined to produce Macadam, "son of Adam," which the English language then took up and further molded to suit its genius.

Trade Notes and Formulæ

Celluloid on Wood.—A good glue for pasting celluloid to wood consists of thick collodion to which is added a small quantity of zinc oxide.—*Zeitschr. f. Drechsler.*

Caterpillar Glue.—Such a glue which neither dries out nor runs may be made by melting together 1 part each of paraffin and soft soap, 2 parts of galipat and 3 parts each of resinous tar and turpentine.—*Seifensieder Zeitung.*

To Remove Verdigris from Halftones.—A mixture of acetic acid and common table salt is a good remedy for the removal of verdigris from the face of electros and halftones. Dissolve the salt thoroughly and apply with a toothbrush.—*Caxton Magazine.*

Improving Shaving Soap.—The addition of a concentrated decoction of the fruit of the soap tree (*Sapindus rarak*) to shaving soap highly improves the latter. It causes the formation of a rich foam of a characteristic cream-like consistency.—*Seifensieder Zeitung.*

Fireproof Paint for Shingle Roofs.—Coat the shingle with hot coal tar, followed immediately by a second application, then sprinkle with ground brick clay. The coating will turn to a hard mass within a few days, which will be fireproof as well as waterproof.—*Prakt. Wegweiser.*

Acid Proofing of Wood.—Melt together in an iron kettle 6 pounds wood tar and 12 pounds resin, then stir in 8 pounds of finely powdered brick dust. The wood must be perfectly clean and dry before being painted over by the warm preparation. Wood will thus be made acid and chlorine proof.—*Mexic. Mining Jour.*

Liquid Coloring for Butter.—(a) Esseptial extract of annatto, 1 part, and Provence oil, 48 to 49 parts; or (b) dry powdered annatto, 5 parts, and Provence oil, 70 parts. Powder and oil are heated on the water bath for one and one-half hours. The liquid is then decanted and filled into dark, well-corked bottles.—*Seifensieder Zeitung.*

Indelible Non-actinic Blue Wrapping Paper.—The *Papier-Zeitung* gives the following formula for a blue wrapping paper which is strong and non-transparent and of indelible color: Unbleached linen, half pulp 30 parts, old documents, not made from wood pulp 20 parts, unbleached Mitcherlich cellulose 40 parts, reddish ultramarine 5 parts, Paris blue 0.5 parts, and size 4.5 parts.

Lubricant for Stopcocks.—Melt on the waterbath 8 parts of commercial ceresine (free from resin) 42 parts of neutral wool fat (lanuline) and 25 parts of spindle oil, mixing thoroughly. Remove from the fire and stir in 25 parts of graphite (flakes), in small portions at a time. Keep up stirring (to prevent the graphite from settling) until it becomes a thick mass. —*Tech. Rundschau.*

Protection Against the Wood Worm.—Wood and articles made of such may effectively be protected against the attacks of the wood worm by treatment with a decoction made of the following ingredients: Sodium chloride, 1 part; pepper, 1 part; powdered mustard seeds, 1 to 2 parts; garlic, 1 part; wormwood leaves, 1 part, and triple vinegar, 2 to 3 pints.—*Neueste Erfind. u. Erfahr.*

Cement for Pasting Together Celluloid Articles.—Several formulæ have been proposed for pasting celluloid articles. One which is found serviceable is the following: Prepare a mixture of three parts of alcohol and four parts of ether and keep this in a well stoppered bottle. When two surfaces of celluloid are to be placed together, wet them thoroughly with this mixture and repeat the operation until the substance has become softened, and then press them together for twenty-four hours. Another solution which may be used is one containing one part of camphor in four parts of alcohol, to which one part of shellac scale is added. This cement must be applied hot.—*Le Temps.*

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